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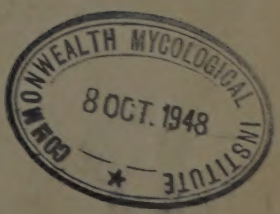
EDITED BY
H. R. OPPENHEIMER and I. REICHERT
of the Agricultural Research Station, Rehovot, Israel

EDITORIAL SECRETARY:
J. PALTI



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Volume VI
(1 9 4 7)

REHOVOT, ISRAEL

CONTENTS

A LAUREL FOREST IN PALESTINE
(Lauretum quercetosum infectoriae)

By H. BOYKO.

While mapping the natural vegetation of the El Fureidis-catchment area (more correct the whole area from the coast line near Athlit and Zikhron Yaaqov to the West, and Daliat il Karmil and Ramat Hashofet to the East)(5) I found a relatively large area in the North-Eastern part of the mapped region, in the vicinity of Daliat il Karmil and Muhraqa, covered with remarkable stands of *Laurus nobilis*. This indicates a much higher humidity or precipitation in this region than in the other parts of the Carmel mountain range.

ECOLOGICAL REMARKS ON LAURUS NOBILIS.

Inter alia a great number of measurements were taken in order to establish the influence of the IE-factor (IE=Insolation-Exposure). Thus the "shifts in amplitude" for Palestine with changing conditions could be recognized (fig. 1). They led to the conclusion that the average annual rainfall in this area must approximate 900 mm., as is to be seen from the following graph.

The method of establishing climatic factors q u a n t i t a t i v e l y by the method of the "shifts in amplitude" is described in detail elsewhere (4 and 6). The graph (fig. 1) speaks for itself, and the behaviour of *Laurus nobilis* at this southern border of its macro-distribution (i.e. its general geographical distribution) is clearly seen from it.

At the same time the exactitude of the "Geo-ecological Law of Distribution" is shown strikingly by this ecological adaptation and by the "microdistribution" (i.e. the topographical distribution at a restricted locality) of this North or perhaps rather North-East Mediterranean tree; this allows by inference, quantitative determinations of certain climatic factors.

It is known of old, that plants are the most sensitive manifestation of a climate, but up to now this could not be evaluated in a satisfying way. Nature writes a highly exact record of every area's climate by means of its natural vegetation cover, but we failed to understand it sufficiently, not knowing to read the alphabet of her writing. The method of the "shifts in amplitude" may prove a suitable step to decipher this script and open the way for the establishment of biological scales not only for single factors but also for the whole complex decisive for plant life, animal life, and human life as well.

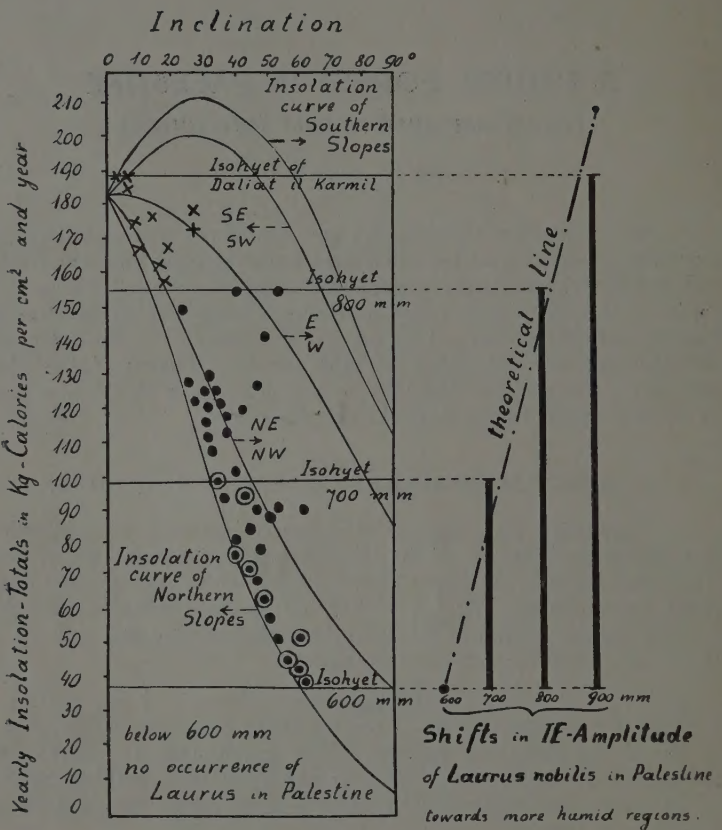

Fig. 1.

Determination of average yearly rainfall for the hills between Muhraqa and Daliat-il-Karmil by the plantsociological method of the "Shifts in Amplitude", using the IE-amplitude of Laurus nobilis L. Its microdistribution indicates for these hills an average precipitation of about 870 mm yearly.
(The insolation curves taken from the book on sun radiation by D. Ashbel (1) refer to the latitude of Jerusalem (31°48'N).

◉ = Stations of Laurus nobilis in areas below 700 mm. yearly rainfall (Occurrence in the Quercetum calliprini lauretosum)

● = Stations of Laurus nobilis in areas below 800 mm. yearly rainfall (Occurrence in the Quercetum calliprini lauretosum)

✖ = Stations of Lauretum infectoriae (Laurus with Quercus infectoria, etc.), only in areas with more than 800 mm. yearly rainfall.

The manifold tables of meteorological figures analysing the climate, and used also for agricultural, silvicultural, etc. purposes are, of course, extremely valuable, but we feel that something has to be added to complete the understanding of climate in relation to living beings. Quite apart from all phenological investigations it can be assumed that such *biological yardsticks,* as attained here by the method of the "shifts in Amplitude" with Laurus as example, are suited to fill this obvious gap, and it is to be hoped that international scientific cooperation will favour and accelerate investigations undertaken for such purpose (4).

PLANT SOCIOLOGICAL ANALYSIS OF LAURETUM QUERCETOSUM INFECTORIAE(*).

The occurrence of such *Laurus nobilis* stands seems to be rare. The most impressive, dense *Lauretum* I remember to have seen is the well known *Laurus-* belt of Mte. Maggiore in Istria up to 300 m. above sea-level. RIKLI (19), in his monumental work "Das Pflanzenkleid der Mittelmeerländer", also mentions the scarcity of proper laurel stands in the Mediterranean region, but it is to be stressed that with regard to the Eastern Mediterraneis his survey is based neither on so extensive a literature nor on studies of his own, as is the case with regard to the other Mediterranean countries.

In the northern sections of the Near East, *Laurus-* stands similar to ours probably occur more frequently but have not yet been analysed by modern plant sociological methods.

The following table shows the detailed structure of this interesting forest-association found on Mount Carmel.

The underlying rocks can easily be determined by the frequent outcrops. I did not find rocks other than hard limestone. According to PICARD (16) these belong to the Upper Cenoman.

The plants of rock fissures and of the openings are not recorded in Table I, as they do not belong to the undisturbed *Lauretum infectoriae.* Table II shows the plants of the openings separately.

Records Nos. 4-7, and 9-14 were taken in the hills South-East of Daliat il Karmil in October and November 1946, records Nos. 1, 2, and 8 near Muhraqa in May 1947.

Table I shows a gradual degradation from record No. 1 to No. 14, according to human interference by fire, cutting, grazing, etc. On Southern slopes the density of Laurus decreases with the growing inclination i.e. with the increase of insolation. At an inclination of about 10° South (see record No. 14) we witness the transformation of the *Lauretum infectoriae* into a *Quercetum calliprini lauretosum,* as this society was called by the author in former articles (2 and 3).

(*) For the sake of brevity this association is called in the following: Lauretum infectoriae.

TABLE I: LAURETUM INFECTORIAE

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
Area in metres	5x5	5x5	10x10	5x5	10x10	10x10	20x20	5x5	5x5	20x20	20x20	20x20	10x10	20x20
Exposure (Slope degrees, direction)	0	0	10	10	0	40	25	5	0	5	5	10	20	10
	—	—	N	N	—	W	NE	NE	—	S	S	W	E	SW
Cover of openings	?	?	20%	15%	35%	20%	40%	?	25%	40%	35%	15%	40%	35%
I. *Characteristic species*:														
Laurus nobilis	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.2	4.3	4.3	4.3	3.2	4.3	2.1
Quercus infectoria	3.2	3.2	3.2	3.2	3.1	3.2	2.1	3.2	—	2.1	2.1	2.1	—	—
Pistacia Terebinthus*)	2.1	2.1	2.1	—	—	2.1	—	—	—	—	—	—	—	—
Rhamnus punctata*)	2.2	2.1	—	2.1	—	—	—	—	—	—	—	—	—	—
Rhamnus Alaternus	2.1	—	—	—	—	—	2.1	—	—	—	—	—	—	—
Ruscus aculeatus	3.1	3.1	3.1	3.1	—	—	2.1	—	—	—	2.1	—	—	—
*) = species with the highest fidelity.														
II. *Characteristic species of the Alliance* (Quercion calliprini *ad interim*)														
a) Trees and shrubs:														
Quercus calliprinos Webb.	4.3	4.3	3.2	4.3	3.2	4.3	3.3	4.3	3.2	4.3	4.3	4.4	3.2	3.2
Phillyrea media	4.2	3.2	—	—	3.1	3.1	2.1	—	2.1	3.2	3.2	3.2	3.1	—
Pistacia palaestina Boiss.	—	2.1	2.1	2.1	3.2	3.2	2.2	—	2.1	2.1	—	3.2	2.1	3.2
Olea Oleaster Hoffm. et Lk.	—	—	2.1	2.1	—	—	3.2	—	—	3.2	3.2	2.1	—	2.1
b) Climbers:														
Asparagus acutifolius	—	—	2.1	—	—	—	2.1	2.1	—	2.1	—	—	—	—
Rubia brachypoda	2.1	—	2.1	2.1	—	2.1	2.1	—	3.1	—	—	2.1	—	—
Smilax aspera	—	3.1	2.1	—	2.1	—	3.1	2.1	—	3.1	2.1	3.1	—	2.1
Tamus communis	3.1	3.1	2.1	3.1	—	2.1	2.1	—	—	—	2.1	2.1	—	—
c) Herbaceous layer: (Perennials)**)														
Arum sp. (palaestinum) (fol.)	2.1	—	—	2.1	—	—	2.1	—	—	2.1	—	—	—	—
Cyclamen persicum	—	—	2.1	—	2.1	2.1	2.1	2.1	—	2.1	—	2.1	2.1	—
Oryzopsis coerulescens	—	—	—	—	—	—	2.1	2.1	—	2.1	—	2.1	—	—
Oryzopsis miliacea	—	—	—	—	—	—	2.1	—	—	—	—	2.1	—	—
Stipa bromoides	—	2.1	—	—	2.1	—	3.1	2.1	—	2.1	—	2.1	2.1	—
III. *Species from degraded stages* (approx. in the order of increasing degradation):														
Rhamnus palaestina	—	2.1	2.1	—	2.1	—	2.1	2.1	2.1	2.1	2.1	3.1	—	3.1
Pistacia Lentiscus	—	—	3.1	2.1	2.1	2.1	3.3	3.2	—	4.2	3.2	2.1	3.2	2.1
Crataegus cf. Azarolus	—	—	—	—	—	—	2.1	—	—	—	2.1	—	2.1	2.1
Cistus villosus	—	—	—	—	2.1	—	—	4.3	—	2.1	—	2.1	—	2.1
Genista sphacelata	—	—	—	—	—	—	—	—	—	—	—	—	—	1.1
Cistus salviifolius	—	—	—	—	—	—	—	2.1	—	2.1	—	2.1	—	2.1
Styrax officinalis	—	—	—	—	—	—	—	2.1	—	—	—	—	—	—
Calycotome villosa	—	—	—	—	2.1	—	2.1	—	3.2	4.2	4.3	—	2.1	3.2
Poterium spinosum	—	—	—	—	—	—	—	—	—	2.1	2.1	—	—	4.3

Remarks: The names of the species in this table (as in the whole paper) are given according to POST, G. E. and J. E. DINSMORE: Flora of Syria, Palestine and Sinai. Beirut, 1932. The names of the authors are added only where names from other sources are used.

**) In the plots No. 9, 11 and 14 the herbaceous layer was not recorded.

Detailed analytical tables of the many sample squares taken from the *Quercetum calliprini lauretosum* by the author have not yet been published. An approximate picture is given, however, in a record by the late A. EIG, published in 1946 in the "Synopsis of the Phytosociological Units of Palestine" (11).

This synopsis, although an extract only, shows already the extremely valuable plant sociological and phytogeographical material left by the late A. EIG in manuscripts and in his diaries.

The authorship of the name *"Quercetum calliprini lauretosum"* belongs to EIG in spite of the fact that this name has been published earlier by the writer (2 and 3). The authorship of names of plantsociological units — if such an authorship is desirable at all — has to be referred to those who publish the first analytical description. Without such a rule every plot where any plant species dominates could be called "x-etum"; such terms would not be generally applicable and lead only to growing confusion among botanists, silviculturists, and even plant sociologists.

At the openings between the trees and shrubs in our *Lauretum infectoriae* a rather poor annual and other herbaceous vegetation appeared in spring 1947; the exceptionally low and late rainfall of the 1946/1947 season is perhaps to be held responsible. The following records (Table II) give a picture of its composition.

It is most significant for the relatively humid climate here, that even in these openings of the 30 species recorded only four, namely *Brachypodium distachyum, Bromus Alopecuros, Psilurus aristatus* Duv.-Jouv., and *Lagoecia cuminoides* — though also of more or less omni-mediterranean distribution — penetrate somewhat deeper into the steppic and more arid region. The first three, however, appear only on spots with very shallow soil, whereas *Lagoecia* has rather a wide amplitude. All others (i.e. 87% !) belong chiefly to the North- or Northeast Mediterranean region or penetrate even into the Euro-Siberian zone.

Description of the records of Table II:

1.) Locality: hill South of the cross-road Daliat-il-Karmil and Muhraqa; plot: 1 square meter; slope: 5° to North; rock surface 60%; whole open place about 4 m². Measurements of soil-depths taken in the square metre of the sample plot of the record delivered the following figures: 10, 15, 12, 8, 10 cms.

2.) Locality: hill as in No. 1; 1m²; 10° to North; covered by creeping branches 30%, rock surface 50%, bare soil with annuals and other herbaceous vegetation 20%. Bushes, around the open space, about 2 m. high (*Laurus nobilis, Quercus calliprinos, Phillyrea media, Calycotome villosa*). Soil deeper than in No. 1; figures lost (one was>50 cm, the others similar to record No. 3).

3.) Locality: hill as in No. 1; Shadowy border of bushes; the size of the plot has therefore not been recorded and only abundance is stated. Soil depths: 18, 35, 24, 32, 40 cms.

TABLE II.

Records from openings in the Lauretum infectoriae on T. *May*, 1947.

Geographical symbol	Species	1. shallow soil	2. deeper soil	3. bush border
om (St)	Brachypodium distachyum	2.1	—	—
om (St)	Bromus Alopecurus	2.1	—	—
nm (St)	Psilurus aristatus Duv.-Jouv.	2.1	—	—
om (N)	Caucalis leptophylla	2.1	—	—
om (N)	Minuartia tenuifolia Hiern.	2.1	—	—
nm	Lens Lenticula	2.1	—	—
nm	Crucianella latifolia	2.1	—	—
nm	Rhagadiolus edulis Gaertn.	2.1	—	—
om (N)	Galium Aparine	2.1	—	—
om (N)	Lolium rigidum	2.1	2.1	—
om (N)	Koeleria phleoides	2.1	2.1	—
om	Briza maxima	2.1	2.1	—
om (N)	Filago germanica	2.1	2.1	—
nm	Cynocrambe prostrata	2.1	2.1	—
om (N)	Dactylis hispanica Roth	—	2.1	—
NE-m	Althaea setosa	—	2.1	—
NE-m	Anthemis melanolepis	—	3.1	—
NE-m	Trifolium erubescens	—	3.1	—
NE-m	Orchis sancta	—	2.1	—
om (N)	Althaea hirsuta	—	2.1	—
nm	Phleum subulatum	—	3.1	—
NE-m	Serratula cerinthifolia	—	2.1	—
NE-m	Galium articulatum	—	2.1 (soc. 2)	—
NE-m	Galium hierosolymitanum	—	2.1	—
				(Abundance)
om (St)	Lagoecia cuminoides	3.1	3.1	2
om	Ononis mitissima	2.1	3.1	3
om	Geranium purpureum	3.1	4.2	4
om	Oryzopsis coerulescens	—	2.1	3
nm	Stipa bromoides Dorfl.	—	2.1	4
om (N)	Ruscus aculeatus (seedlings)	—	—	3

Abbreviations: om = Omni-mediterranean
nm = mainly North-mediterranean distribution
NE-m= North-East-mediterranean
(N) = penetrating from the Mediterraneis further North
(St) = penetrating into steppic regions
Sociability (soc.) is mentioned only if necessary, i.e. if a certain grouping is remarkable and specific for the species in question.

Although nearly all the species listed in Table II have their southern limit in Palestine, and are, therefore, more or less indicators for relatively humid habitats, the order of the table follows an indefinite scale of increasing hygrophilous adaptation (preference of shadow, lower temperature, etc.). Of the species quoted *Lagoecia cuminoides* should have its place among the first four or five species. In spite of its rather wide amplitude it is a sensitive indicator for the degree of soil dryness, indicating it by its general development, particularly by its height and the number of its umbels. On the other hand, *Cynocrambe prostrata* would have been expected to occupy a lower place in this list.

Average heights of the plants have been recorded. On places with shallow soil cover the height of annual plants is in most cases a fair indicator for the depth of the soil' for its moisture content, and — if comparative measurements are at hand from other years from the same locality or from many similar localities — for the actual rainfall of the preceding season.

The few initial observations carried out by the author showed a strikingly close correlation between the height of some annuals and the annual rainfall. Observations on a broader scale and over a number of seasons for selection of the species most suitable as indicators for this fundamental meteorological factor seem highly promising.

(For the purpose of measuring the soil depth in my ecological studies I use an iron rod, 50 cm. long and 6 mm. broad, pointed at one end, and provided with a suitable handle. The length of this simple and cheap tool is sufficient for our purpose and enables us to attach it conveniently to the side of the plant press. In a sample plot of one square metre soil depth at five points is very easily and quickly determined with this instrument, producing a fair picture of soil depth for the whole plot).

The remarkably high percentage in Table II of annual and a few other herbaceous species with North-East-Mediterranean distribution (23%) similar to that of the two woody species most characteristic of the *Lauretum infectoriae, Quercus infectoria* and *Rhamnus punctata,* and probably of *Laurus nobilis* itself, deserves to be mentioned. This applies particularly to the record No. 2 with its deeper soil.

In both phyto-sociological tables the usual scales of Braun-Blanquet (8) have been used: the first figure therefore represents the abundance, the second the cover of each species. The sociability of the main woody plants is seen from Fig. 2, representing a typical plot (record No. 4 in table I).

Considering the ecological and historical features of *Lauretum infectoriae* the whole space inside the isohypses from about 450 m above sea level on had to be recorded in the mapped catchment areas (5) as this climax forest type. The whole area covers approximately 10,000-15,000 dunums (i.e. 10-15 square kilometres), at present partly

transformed already into fields with scattered stunted *Laurus* bushes and other remainders in their midst. It seems highly recommendable to proclaim at least a small part of this area as a protected sanctuary to preserve one of the very last *Laureta nobilis* of the world.

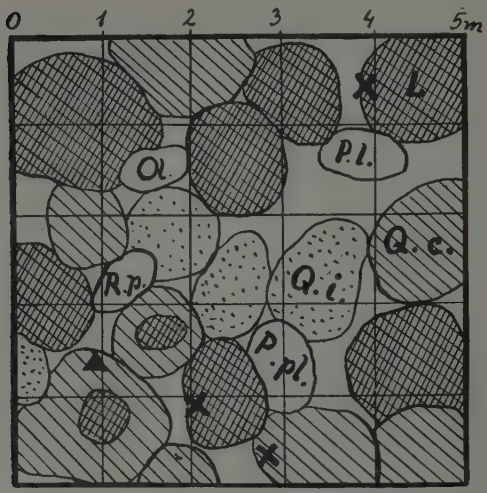

Fig. 2.

		Height m
L	= Laurus nobilis	0.4-2
Q.i.	= Quercus infectoria	0.4-3
Q.c.	= Quercus calliprinos	1-2.5
R.p.	= Rhamnus punctata	0.8
P.pl.	= Pistacia palaestina	0.5
P.l.	= Pistacia lentiscus	0.5
Ol.	= Olea europaea var. Oleaster	1.8

× = Tamus communis

▲ = Rubia brachypoda

(Nearly all specimens are cut and browsed).

REMARKS ON THE CHARACTERISTIC SPECIES.

A distinct plant society (association in the sense of Braun-Blanquet [8]) cannot be described satisfactorily without elaborating one by one the characteristic species, which alone give a true picture of its ecological requirements, its floristic individuality, and its stage of development. A few short remarks on the characteristic species of the *Lauretum infectoriae* are therefore added:

Laurus nobilis: the most important features of its ecological requirements emerge from the graph (Fig. 1); (see also the historical remarks on page 10—11).

Quercus infectoria and *Rhamnus punctata* are both species from the northern and more humid parts of the Middle East. They are good differential species between our Lauretum and the Lauretum mentioned from Mte. Maggiore in Istria. The occurrence of *Rhamnus punctata* in Palestine as a characteristic species in a related plant society with a similarly humid ecoclimate (Quercetum calliprini infectorietosum) is mentioned already by N. Feinbrun (13), and it is also found in the record of the society Quercetum calliprini lauretosum in the synopsis by A. Eig (11).

Pistacia Terebinthus occurs here in its *typical* form. The variety palaestina (syn. *Pistacia palaestina* Boiss.) appears in the more degraded stages with higher insolation and drier soil. Transition forms are frequent.

The tendency to split species into smallest units without genetical foundation and to give them specific value led *inter alia* also to the exclusion of *Pis-*

tacia Terebinthus from the flora of Palestine*). This appears unjustified. Proof of this assertion is offered by specimens preserved in the Herbarium Boyko, Jerusalem.

Rhamnus Alaternus is a shrub characteristic of the more humid forest associations of Palestine; compared with the other characteristic species its fidelity is somewhat lower.

Olea Oleaster, i.e. the wild *Olea europaea* (var. Oleaster) seems also to be a characteristic tree of the more humid forest associations in Palestine, but its fidelity is even lower than that of *Rhamnus Alaternus,* and it is, therefore, enumerated in Group II.

Ruscus aculeatus, however, is most characteristic by its high frequency, its abundance, and last not least by its easy natural reproduction. Indeed many seedlings of Ruscus have been noted. Classifying the vegetation type of our society according to H. Brockmann-Jerosch and E. Ruebel (9) we note a typical example of the formation-group "Laurisilvae".

THE ROLE OF QUERCUS CALLIPRINOS AND A RECONSTRUCTION OF AN UNDISTURBED CLIMAX FOREST.

Quercus calliprinos Webb. (=*Qu. coccifera* var. *calliprinos*) is the most conspicuous bush in nearly all Palestinian forest remnants of the Mediterranean zone. It seems to be of primary occurrence also in the *Lauretum infectoriae* forest but increases in abundance and dominance only with the cutting or burning of *Laurus.* This oak is the most frequent constant in the society but by no means one of its characteristic species.

The dense canopy of this Laurus forest — if in a well developed stage — produces a degree of illumination insufficient for natural reproduction of either of the species of Quercus, whereas it seems to suffice for the germination requirements of Laurus.

The same applies to nearly all other Mediterranean maquis plants except some climbers and *Ruscus aculeatus.* Some of the climbers and *Ruscus* as well seem to be even more abundant in such dark environment; the former "aim" at reaching higher layers of the canopy where light conditions are better, while the latter are satisfied with a relatively very low intensity of light during their whole lifetime.

A *theoretical reconstruction of the climax forest* for this part of Palestine can be undertaken on the basis of the many stages of degradation observed. Near Muhraqa this climax forest must have been intact till quite recently. The type must have been a more or

*) A similar case is, for instance, the exclusion of *Quercus Aegilops* (7). Recently Dr. N. Feinbrun and her pupils introduced the very important cytogenetical investigations into the systematics of the flora of Palestine.

less dense *Laurus* forest with many old trees possibly several hundreds of years old, and with a dominance in the canopy of about 4-5 at heights of 5 to 7 metres. This dense crown canopy can be assumed to have been overtopped at ten and more metres by single old trees or small groups of *Quercus infectoria,* which may have had the chance of natural regeneration in occasional openings.

In such gaps *Quercus calliprinos* may have played a similar rôle together with the other maquis shrubs, but only rarely overtopping the shrub layer and reaching the two highest storeys: the *Laurus* canopy storey and the *Quercus infectoria* storey. Generally *Quercus calliprinos* is lower than *Laurus* and will therefore have been suppressed again in the course of time. Mammals (rodents and even wild pigs eradicated from these forests only few decades ago), birds, and many insects contribute to the suppression of natural reproduction and of growth of this oak and were probably assisted by plant parasites under these unfavourable ecological conditions.

Some physiological aspects of the difficult reproduction of *Quercus calliprinos* have also been mentioned by H. R. Oppenheimer (15); the writer's own observations and measurements of its small ecological amplitude of seed germination will be published elsewhere.

Cyclamen persicum (leaves only), *Ruscus aculeatus, Arum sp., Geranium purpureum,* and a few others are the main representatives of the scarce surface vegetation among the numerous stems of Laurus and some climbers. For the openings in a Lauretum the Madonna Lily (*Lilium candidum*) may also be one of the characteristic species. (3).

A few historical remarks may be added to this picture: *Laurus nobilis* — and perhaps in its general outlines the whole plant-community — is to be regarded as an important component of the vegetation of Palestine during the Pluvial, at least as by far more important than at present.

It is to be assumed that *Laurus* as a well known tertiary species of northern origin migrated further South in the Pliocene, and found here and in other Mediterranean countries its refuge during the Pleistocene. In the sense of I. Reichert (18) it is a humid-mesothermic "type", and — like many others of the Mediterranean maquis "components"—a Miocene "element", and a Pliocene "migrant". From the present localities of *Laurcta* in the Mediterranean region the climate of Central-Europe in the Miocene can be reconstructed with great probability as Laurus shows a particularly high sensitiveness to climatic changes. The graph in Fig. 1 gives striking proof of this assumption.

The main climatic requirements of *Laurus nobilis* are twofold: In respect of humidity it seems to require a NS-quotient (Mayer's

quotient, i.e. precipitation : saturation deficit quotient) of approximately 250-300, and in respect of temperature mild winters with occasional and slight frosts only. With the figures of M. Y. NUTTONSON's (14) comparative agro-climatic study at hand, and with the data given by R. FEIGE and E. ROSENAU (12), it can be assumed that the "precipitation effectivity index" of the localities where our Lauretum occurs is about 70.

From the Upper Pleistocene on and during the Holocene period dense *Lauretum infectoriae* forests, as described above, covered the cooler and more humid parts of the mountains of Palestine in a rather undisturbed stage.

In historical times man appeared on the scene and changed the situation completely with his axe, fire, and goats.

The first stage of this degradation led towards preponderance of *Quercus calliprinos* and other maquis shrubs. The second stage, with a still higher light intensity brought the intrusion and quick expansion of *Pistacia lentiscus;* the third that of *Cistus villosus* and *Cistus salviifolius;* — the former Cistus species, however, came earlier (!) than the latter —; and so on, as indicated in Group III of Table I.

On the other hand *Quercus calliprinos* seems to be of particular importance for the regeneration of the original vegetation here. On some places we can find nearly in every oak bush a small *Laurus nobilis* specimen sprouting in its dense shadow, either from seed or from an old stump. Sometimes we can see how *Laurus* is slowly overtopping the oak, suppressing it in due course and forcing it into a lower layer, till finally it will build up again its own dense leaf canopy after a few hundred years. The darkness under this canopy will provide suitable conditions of existence only to a small number of plant species like *Ruscus, Arum,* etc., forming a sparse surface vegetation. Mosses may be of high sociological importance in the whole biocenosis, and so may even certain lichens as described by I. REICHERT in his lichenogeographical paper on *Dirina Ceratoniae* (17).

On these hypothetical lines the composition of this climax forest can thus be sketched as follows :

TABLE III.

Hypothetical composition of an undisturbed Lauretum infectoriae :

Upper tree layer (*Height* 7-10 *m*) :	
Quercus infectoria	3.2 (soc. 2)
Lower tree layer (*Height* 5-7 *m*) :	
Laurus nobilis	5.5 (soc. 5)
Quercus infectoria	3.2 (soc. 2)
Quercus calliprinos	3.1 (soc. 2)
Pistacia Terebinthus	2.1 (soc. 1)

Upper shrub layer (*Height 2-4 m*):

Quercus calliprinos	3.2 (soc. 3)
Phillyrea media	3.1 (soc. 2)
Arbutus Andrachne	2.1 (soc. 1)
Pistacia Terebinthus	2.1 (soc. 1)
Rhamnus punctata	2.1 (soc. 1)
Viburnum Tinus	2.1 (soc. 1)
Myrtus communis	2.1 (soc. 1)

Lower shrub layer: *very sparsely occurring only.*

Climbers:

Tamus communis	3.1
Tamus orientalis	2.1
Clematis cirrhosa	3.1
Asparagus acutifolius	3.1
Rubia sp.	3.1
Smilax aspera	3.1

Herb layer:

Ruscus aculeatus	3.1 (soc. 1)
Polypodium vulgare	2.1 (soc. 2)
Pancratium parviflorum	2.1 (soc. 2) (fol.)
Arum palaestinum	3.1 (soc. 1) (fol.)
Cyclamen persicum	3.1 (soc. 1) (fol.)
Lilium candidum	2.1 (soc. 2) (fol.)

(the latter four species flowering in openings only).

Moss layer:

Several species possibly with a dominance 2.

On trees: Dirina Ceratoniae among other lichens.

(In all layers rarely only a few further Companions and Accidentals).

SUMMARY:

The paper contains:

1.) Ecological remarks on *Laurus nobilis* L., proving the species to be a very sensitive climatic indicator, enabling us to use it as *quantitative* indicator for humidity (precipitation) by the method of "Shifts in Amplitude". (See Fig. 1).

2.) Palaeo-historical remarks on *Laurus* in Palestine and in the Mediterraneis in general.

3.) A plantsociological analysis of the *Lauretum infectoriae* (a *Laurus* forest with *Quercus infectoria* as characteristic species), a distinct plant society described here for the first time.

4.) A description of stages of degradation leading from, and of the succession stages leading towards the *Lauretum infectoriae* as climax vegetation type.

5.) A theoretical reconstruction of this climax forest which represents a well defined IE — forest type.

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NATURAL REPRODUCTION OF EXOTIC PLANTS IN PALESTINE

By H. R. OPPENHEIMER

It is a well known fact that certain plant species, when introduced into countries distant from their original zone of distribution, breed rapidly and often even come to be a nuisance, while others are incapable of successful reproduction. The latter must be propagated by man, otherwise they soon die out.

The conditions governing the success or failure of the establishment of a natural population of introduced plant and animal species are, of course complex in character. Such success or failure depends in plants on one hand on biological qualities, such as the production of flowers, pollination, seed anatomy, seed distribution by animals, physiology of germination, etc., and on the other hand on climatic factors like temperature and precipitation.

The region between Jaffa and Gaza represents a marginal area of the Mediterranean climatic zone. Here conditions favour the germination of seeds of annuals adapted to cool temperature setting in with the winter rains in November. Consequently, our gardens show an abundance of species such as larkspur (*Delphinium Ajacis* ×*Consolida*), *Phlox Drummondii, Coreopsis tinctoria, Tropacolum majus, Eschscholtzia californica, Antirrhinum majus, Linaria ?maroccana, Gomphrena globosa, Alyssum maritimum, Linum grandiflorum, Dimorphothcca aurantiaca, Scabiosa atropurpurea* and others. Their natural reproduction renders the artificial raising of seedlings superfluous. Gardeners merely abstain from stirring the earth of flower beds cultivated during the preceding rainy season and collect thousands of seedlings from a few square metres.

Annuals adapted to somewhat warmer conditions, such as *Petunia hybrida, Gaillardia pulchella, Portulaca grandiflora, Pelargonium zonale, Zinnia sp., Tagetes erecta,* etc. also often meet conditions favouring natural reproduction by seeds, before the rainy period ends. Their seedlings continue to appear in irrigated flower beds during the hot season. Here we also find seedlings of perennials like *Vinca rosea* and *Leonotis Leonurus.*

Conditions are entirely different for the bulk of perennials, shrubs, climbers and trees introduced into our gardens from other tropical and sub-tropical countries, such as Australia, India, China, tropical Africa and the warmer parts of North or South America. With these plants natural reproduction is the exception rather than

the rule. Often neither fruits nor seeds are produced, as in the case of *Ficus elastica, Plumeria acutifolia, Wisteria sinensis;* or seeds may be formed only once in a number of years, as in *Robinia Pseud-Acacia* (spreading by seedlings in the yards of the settlement of Nahalal in the Esdraelon Valley, as well as at Rehovot in moist localities) or in *Araucaria excelsa* where we observed cone formation at Rehovot in 1946 for the first time since 1933. In more numerous cases, seeds are formed annually but germination is rare or seedlings die in the first year of their existence. Thus, even in shady localities near the mother plant we do not, as a rule, encounter seedlings of *Delonix* (*Poinciana*) *regia, Duranta Plumieri, Jacaranda? mimosaefolia* (*foliis glabris*). Of millions of seeds produced by *Cupressus sempervirens* (native in the Mediterranean region) and by other exotic cypresses, only rare, needle-leafed young seedlings are to be observed. Older spontaneous seedlings with the scaly leaves of the mature tree are seldom found. This situation is essentially a consequence of the hardships of a climate in which rain hardly ever falls during the six hot summer months, and these conditions are often coupled with low atmospheric humidity.

Little attention appears so far to have been paid to the remarkable fact that not a single citrus seedling can often be found in hundreds of dunums of citrus groves in Palestine, though fruits which contain seeds and might thus produce seedlings often drop from the trees in winter and spring. The occurrence of seedlings remained rare even during the last war when the soil was little cultivated and enormous numbers of fruits could not be harvested. The explanation probably lies in the fact that winter temperatures are too low for good germination, while in summer the upper soil layer dries up in the irrigation intervals before germination can lead to the establishment of viable seedlings. We know that citrus and especially sweet orange seeds are easily killed even by slight dehydration.

Natural reproduction of *Eucalyptus* is also exceptional. We find it in the region of Hadera, on heavy low-land soils of a high water storage capacity or in localities such as the Yavneh cooperative settlement where, as we have been told, seedlings of *E. camaldulensis* sprout in places permanently moistened by seepage water. Nor have we so far seen natural reproduction of *Casuarina equisetifolia* or *Grevillea robusta* at Rehovot, in spite of copious seed production, though Mr. Joseph Cohen informed us that he observed *Grevillea* seedlings in tilled soil at the Government Agricultural Experiment Station, Acre. In localities such as the Agricultural School of Pardess Hana, we searched in vain for seedlings under a lane of *Grevillea* producing many thousands of seeds.

Many other species, cultivated in the Acclimatisation Garden for sub-tropical and tropical fruit trees of the Agricultural Research Statio, at Rehovot, fail to reproduce by seedlings. We mention *Diospyros Kaki* (seedless!), *Doryalis hebecarpa, Averrhoa bilimbi* and *A. Carambola, Feijoa Sellowiana, Nephelium Longana.* The same holds

true for ornamentals like *Duranta Plumieri, Nerium Oleander,* and *Spiraea sp. Myrtus communis* germinates at Rehovot only in moist and shady localities.

Our observations at Rehovot justify the statement that natural reproduction of introduced woody plants takes place, as a rule, only where the soil is protected from the direct radiation of the sun but light intensity is not too low to render the development of seedlings impossible. Reproduction is further often conditional on the supply, frequently or permanently, of moisture by irrigation basis, ditches or furrows, or by water draining from kitchens, bathrooms, factories, laundries, etc. Sometimes even small holes collecting and retaining moisture may offer good conditions for seed reproduction. Thus in Jerusalem in July 1947, we observed seedlings of *Ailanthus glandulosa* in the barbed wire entanglements outside Police Headquarters. These seedlings were found developing in tiny holes made in the asphalt cover of the side-walks to erect iron bars supporting the wire. But very few species reproduce naturally under the conditions of the open sunny fields of the coastal plain. Such rare cases are the more remarkable and worthy of special attention as examples of an extraordinary capacity of plant species to endure severe drought, even in a tender, early stage of their development. On the other hand seedlings frequently develop near the stem of shade trees and on the northern flank of walls and houses.

Table I presents information about the natural reproduction of exotic trees, shrubs and climbers, as observed at Rehovot. Species marked with an exclamation mark are relatively common. Of these, *Lantana Camara* and its varieties deserve special discussion. This bush, growing wild in tropical and sub-tropical countries of both Americas like those at the estuary of the La Plata stream, finds favourable conditions for its natural reproduction from seeds throughout the coastal plain of Palestine. During World War II we have been watching its rapid expansion in the neighbourhood of Rehovot, Rishon le-Tsijon and Hadera. The young plant is a shade-bearer sprouting at the outskirts of pine groves, under hedges of *Acacia Farnesiana,* cypresses, sour orange, etc. and under citrus trees planted in groves. Its branches penetrate through the top of their shade trees penetrating their ramifications, adorned with beautiful pink and yellow flower heads, above the latter. Simultaneously, they also spread in a horizontal direction, forming impenetrable cushions and hedges. Thus the *Lantana,* resembling the native *Rubus sanctus* in ecological requirement and distribution, suffocates in our days many hedge plants by its strong growth and its remarkable endurance of both shade and drought. In this respect it resembles even more the indigenous climber *Ephedra campylopoda* and even the shade bearing beech in European oak forests. *Lantana Camara* is very frequent in abandoned and eradicated citrus groves where its seeds have originally germinated in the irrigation

basins and enjoy favourable conditions of development after removal of the citrus trees. In its company we also find seedlings of indigenous species of *Asparagus* (*A. acutifolius, A. stipularis*) and exotic species like *A. plumosus,* seedlings of *Melia Azedarach, Schinus molle* and *S. terebinthifolia, Acacia Farnesiana,* and local plants like *Solanum nigrum,* and occasionally *Withania somnifera.* With the progress of summer drought, we sometimes find the *Lantana* in a state of heavy wilting accompanied by partial shedding of its leaves, but with the onset of winter rains it again forms fresh leaves and flower-heads and no after-effects of damage such as desiccation of branches are seen to persist.

TABLE I

Exotic species of woody plants and climbers of which spontaneous seedlings have been found at Rehovot and in its neighbourhood

Acacia cyanophylla
Acacia Farnesiana
Agave americana
Agave mexicana
Ailanthus glandulosa
Ampelopsis quinquefolia
Ampelopsis Veitchii
Antigonon leptopus
Aristolochia elegans
Asparagus plumosus var. robustus
Brachychiton acerifolium
Brachychiton populneum
Campsis radicans
Casimiroa edulis (*rare*)
Cassia floribunda
Ceratonia Siliqua
Citrus Limon
Citrus medica
Citrus reticulata
Citrus sinensis
Dalbergia Sissoo
Dodonaea viscosa
Eriobothrya japonica
Eucalyptus saligna
(in shady localities only)
Eugenia uniflora
Eugenia Jambos
Eugenia jambolana
Ipomaea palmata
Lantana Camara and others
Laurus Camphora
Melia Azedarach
Morus alba
!*Nicotiana glauca*
Olea europaea
Parkinsonia aculeata
Persea gratissima
!*Phoenix dactylifera*
Phoenix? canariensis
Pittosporum Tobira
!*Plumbago capensis*
Prunus armeniaca
Prunus persica
Prunus salicina hybr.
(Japanese plums)
Punica Granatum
Ricinus communis
(cultivated since thousands of years in Palestine)
Robinia Pseud-Acacia
Schinus molle
Schinus terebinthifolia
Solanum? Seaforthianum
Stillingia sebifera
Tecoma capensis
Tecoma stans
Vitis vinifera
Washingtonia filifera
Wisteria multijuga.

Our ecological observations on *Lantana Camara* L. in the mild coastal plain of Palestine agree well with indications of UPHOF (Mitt. deutsch. dendr. Ges. Nr. 42, 1930, 105—126) regarding the distribution of this species in the sclerophyllous semitropical woods at the Atlantic coast of Florida. UPHOF found it in the shrub layer of open woods on very poor, sandy soil, and especially in a transitional zone where conditions favour the occurrence of rather xerophytic species. By the way its vegetative development in Palestine is by far better in this country than in Florida. There, it is reported to be a small bush, no more than 1.50 metres high, while in this country, it climbs as high as five metres and forms thickets composed of several specimens even broader than that.

At Rehovot climbing seedlings of *Asparagus plumosus robustus* are often found in old gardens enjoying little attendance and irrigation to form at the periphery of shady bushes like *Laurus nobilis, Punica Granatum,* etc. In one case we found it climbing on an old specimen of *Cupressus sempervirens var. pyramidalis,* reaching the top of the tree which suffered seriously by the shade produced by this climber covering one half of its top.

The vast majority of the species mentioned in this paper produce berry-like fruits. There can be no doubt that these are eaten by birds which are the principal agents of seed distribution of those species, besides man who throws away the pips of citrus and grapes and the stones of drupaceous fruits like plums, apricots, olives and dates. The ornithochorous character of seed distribution becomes obvious if we observe *Lantana* seedlings near masts of electrical lines where transformers etc. mounted at their upper end offer bulbuls (*Pycnonotus vallembrosae*), wild pigeons etc. a convenient rest. The distribution of seeds of the above mentioned plant species represents an interesting ecological problem which does not seem to have been studied. The bulbul (Arab nightingale) is evidently the bird responsible in the first line for the distribution of the *Lantanas* which attracts it very much with its black, sweet berries. Other species, like *Ailanthus,* are probably spread by wind.

Finally we wish to stress that our modern settlements imbedded in their green parks and lanes are, so to speak, to this day semi-deserts for the tender seedlings of the perennial species discussed in this article. Of ten thousands of seeds not even one has the chance to develop into a full grown tree or shrub. As in deserts, we find them developing only at places where moisture supply is favoured by local conditions. Thus we found *Brachychiton populneum* growing in one shady garden at both "banks" of an irrigation furrow recalling a desert wadi lined with a "gallery forest" *en miniature.* Even under a thick cover of shed leaves the unirrigated soil is too dry during summer to favour germination and early development. In this respect conditions in gardens resemble those we have described earlier as rendering the reestablishment of natural oak forests in this country so difficult. (Pal.

Journ. Bot., Reh. Ser. 3:105—143, 1939), and those hampering natural reproduction even of most other indigenous species.

SUMMARY

While introduced species of annual plants often sprout easily from seeds during the rainy season, perennial exotic species are rarely found reproducing from seeds. Natural reproduction is generally bound to shady, moist localities. Attention is drawn to the recent expansion of *Lantana Camara* in the coastal plain.

Acknowledgments. The author is obliged for relevant information to the following horticulturists: Messrs W. Hiller, H. Lipmann and Y. Paldi, all of Rehovot, and to Mr. D. Zeidenberg, in charge of the Botanical Garden at Miqveh Israel.

THE DECISIVE ROLE OF DIRECT SUN-RADIATION IN THE DISTRIBUTION OF *QUERCUS AEGILOPS L.* IN PALESTINE

By H. BOYKO.

In the paper "On forest types of the semi-arid areas at lower latitudes" (Vol. V/1 of this journal, 1945) it could already be shown that insolation is a basic factor in the distribution of certain vegetation types in Palestine and all other countries of the Middle East.

As a rough expression of the insolation effect for every point and latitude we measure the angle of inclination and the direction of exposure (see the insolation curves in the annexed graph). Their joint effect was termed "IE-factor" (IE=Insolation-Exposure). Average cloudiness and change with altitude can be considered as constants for each place.

Figures of yearly sums of radiation thus obtained for each habitat could easily be represented graphically. For Palestine the low cloudiness permits their direct application for agricultural and silvicultural purposes in most cases even without the necessity of corrections.

In the course of these studies it was found that quite a number of plant species and plant societies are strictly confined to certain insolation ranges termed "IE-zones". In the following a striking example for such a strict limitation of distribution by insolation shall be dealt with. It concerns one of the few forest building trees in Palestine and the forest types in which it plays the leading role. This tree is *Quercus Aegilops* L., the Valonea Oak.

Quercus Aegilops occurs in Palestine in its typical form, and in several varieties. The opinion that all Valonea Oaks in Palestine are *Quercus ithaburensis* Decsne, is, therefore, erroneous. The bulk of the trees in our forests belong, however, to *Quercus Aegilops* L. var. *ithaburensis* (Decsne.) Boiss. and to one of the many transitional forms between this variety and the typical *Quercus Aegilops*.

Up to now four widely differing types of these oak forests could be distinguished by the author. They are very distinct ecologically and therefore of great practical interest for silvicultural purposes.

The great differences in the ecological features and consequently in the surface vegetation of these four forest types with *Q. Aegilops* as dominant species, will be dealt with in connection with the synecological studies on Mt. Heitary, carried out jointly by the author and Dr. H. R. Oppenheimer.

Investigations have been undertaken for the establishment of the borderlines and the overlapping of the ecological amplitudes of *Quercus Aegilops* on one hand, and of the East Mediterranean Kermes Oak, *Quercus calliprinos* Webb. (=*Quercus coccifera L. var. calliprinos* (Webb.) *Boiss.*) on the other. It could be established that in the hill region, besides a certain vague influence of the geological layer, insolation is the decisive factor in the natural microdistribution of Quercus Aegilops.

We called "IE-types" forest types, and more generally vegetation types, decisively influenced by the IE-factor. The *Querceta Aegilopsis* of the hill region of Palestine are typical examples of such IE-types, as can be seen from the following graph.

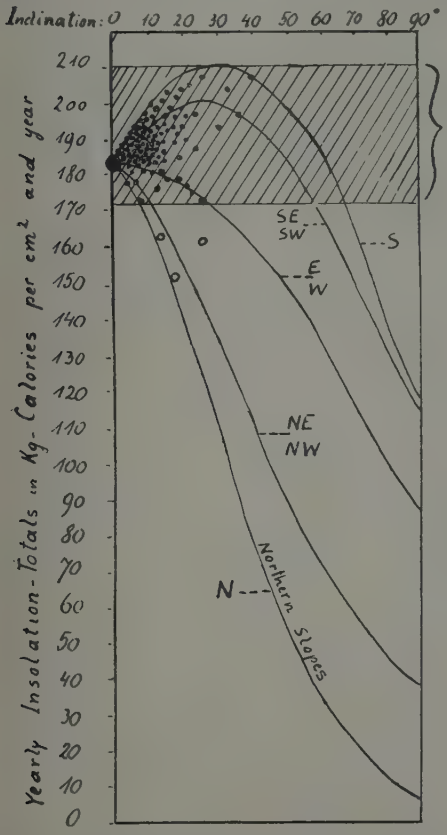

Fig. 1.

IE — amplitude of Quercus Aegilops L. in the Carmel region.

● = Querceta Aegilopsis.

o = single trees as extreme outposts.

(Compare this graph with the graph of Laurus nobilis on pag. 2 of this volume in: 'A laurel forest in Palestine (Lauretum quercetosum infectoriae)" by H. Boyko).

In this graph we used the insolation curves for the latitude of Jerusalem (31°48') taken from the book on solar radiation by Dr. D.

Ashbel (Jerusalem, 1942), and marked a large number of single measurements many of which were taken in extreme habitats. Each dot represents at least one (at the extreme stations), but in most cases a great number of single measurements.

The graph shows that *Quercus Aegilops* is limited to localities with high insolation values as found on slopes with small inclinations in all directions of the compass and on slopes with larger inclinations in Southern, South-Western, and South-Eastern exposures, as indicated by the graph.

On slopes with other insolation figures than those included in the hatched IE-zone of the graph, invariably another vegetation type replacing the *Quercetum Aegilopsis* appeared. In most cases this was one with *Quercus calliprinos* as dominant species.

The problem which seasonal period of insolation plays the decisive role is still to be solved and needs further investigation. At any rate this example shows that the IE-factor must be taken into consideration in afforestation or introduction schemes in semi-arid and arid regions (between the main global forest belts), and that this can be accomplished by a rather simple method, even by unskilled persons, once the IE-amplitude has been established.

The world wide organisation in agro-meteorological research shows still a gap in semi-arid and arid regions of lower latitudes. Here bio-meteorological and ecological observations on the lines discussed here are expected to yield promising results, if carried out on a large scale by an international network. For, the small IE-amplitude of *Quercus Aegilops* in Palestine is certainly only one example out of many others.

AGAIN ON CAMBIAL ACTIVITY OF ALEPPO PINE

(A REPLY TO Dr. H. R. OPPENHEIMER'S CRITICISM)

By I. GINDEL

(Forest Research Laboratory, Agricultural Station of the Jewish Agency for Palestine, Rehovot).

H. R. OPPENHEIMER's report on cambial activity of Aleppo-pine (9) is based mainly on data collected from 3 trees (2 dominant and 1 subdominant) of a young grove only 15 years old. That grove grows in relatively deep soil, at the foot of a hill and belongs to the experimental areas of the Forest Research Laboratory. According to measurements in 1941, it showed *optimal* development as compared with the 62 sample plots established by this Laboratory in artificial Aleppo-pine forests of the country. On the other hand, the data represented in my earlier article (3) criticized by OPPENHEIMER have been collected from trees grown under adverse ecological conditions, such as rocky ridges, steep slopes exposed to desiccating, often hot winds, or on southern exposures.

Fig. 3 of my paper demonstrates the growth of 2 neighbouring pine trees. One of them grows among rocks on the top of the hill, the other at the foot of that hill, but in deep soil with abundant moisture and is protected against desiccating winds by the slope of the hill. That figure illustrates clearly how complacent is the growth of the latter tree and, although its age is nearly 50 years, no differentiation in ring structure can be noted. Such trees therefore absolutely do not fit the purpose of studying the correlation between climatic factors and ring structure. The upper tree grown under bad ecological conditions in rocky soil shows large differences in the structure and width of its rings. Even in "sensitive" trees it is difficult to trace any correlation between climatic factors and tree ring structure before the trees reach the age of 25—30 years.

The data collected by OPPENHEIMER cannot, therefore, serve as a basis for tree ring analysis for the following reasons: 1) the optimal ecological conditions under which his trees grow, 2) the young age of the trees, 3) the very scarce number of trees under his observation, and 4) the short period of his studies on this subject (one year only). Taking into consideration the huge world literature on this subject and the relatively abundant data collected by myself during the last 4 years, we would like to counter his criticism with the following remarks.

1) OPPENHEIMER is sceptical as regards the influence of temperature and soil moisture on the structure of tree rings. That influence has been established by many workers such as KLEINE, POTSGER and FRESNER (5), GLOCK (4), DOUGLAS (2), KOLMODIN (6), LYON (7), MAC DOUGAL (8) etc. All of them, and many others have shown that precipitation and temperature are the dominant factors affecting the rate of tree growth in semi-arid conditions. The influence of temperature may be direct, by initiating cambial activity, or indirect by affecting evaporation, transpiration and humidity.

ANTEWS in his book "Rain Fall and Tree Growth in the Great Basin" (1938) asserts that temperature, especially the duration of favourable temperature and the range of its fluctuations during the normal growing season, is decisive

for the rate of growth. He further concludes: "In the semi-arid region of the west, where periods of inadequate water supply may occur during a growing season that is *favourable with regard to temperature, scarcity of water* may dominate the situation and largely determine the amount of growth".

MC DOUGAL (8) who tested soil moisture and tree growth in California concludes that soil moisture is seldom replenished during the summer and cambial activity ceases then, only to be resumed if autumn rains occur. MC DOUGAL (8) claims that "artificial irrigation of *Pinus radiata* during July resumes cambium activity *interrupted* some time earlier because *of soil moisture depletion*". According to PEARSON (10) exhaustion of growth water, to a depth of 12 cm. may occur at the end of June. SERRANO (12) found that the higher temperature the less moisture is the plant able to get from the soil before wilting. Interruption of cambium activity due to lack of moisture is a well known feature, particularly in regard to trees grown on the boundaries of the forests. BRADY (1), for instance, who tested *Pinus ponderosa* in such conditions, found some clear alternating layers in each annual tree ring. He and other workers explain this phenomenon as caused by alternating wet or dry periods during the same growing season which cause the interruption of growth during the period of dryness.

LYON (7) found correlation between growth of trees and March-April temperatures. Many more authors can be cited, but the evidence adduced above is quite sufficient to the conclusion that temperature is one of the important factors influencing tree growth directly and indirectly.

2) OPPENHEIMER's claim that he has "never been able to find an interruption of cambial activity so early in the season" appears thus to be rather inconclusive especially if we bear in mind that, as mentioned above, he has tested for a period of one year only young trees grown under conditions entirely unsuitable for ring analysis.

3) OPPENHEIMER's argument that lack of water as a condition directly conducive to the formation of late wood has been disproved as early as 1899 by SCHWARZ (9), is entirely unfounded in this case as far as the growth of Aleppo pines is concerned. It must be borne in mind that SCHWARZ has carried out his experiments in a cold wet climate on *Pinus sylvestris* which grows in deep, mainly light soil. Besides, on page 371 of SCHWARZ's (11) book, he concludes that a low summer wood percentage corresponded with a low rainfall and vice versa. SCHWARZ has also found a positive correlation between ring width and mean air temperature in January-March; a high ring width often corresponded with a low May and June temperature.

4) It is to be regretted that thus far only very scarce data is available in this country as regards the effect of the hot desiccating winds, called 'khamsins', which extend often over 28—30 days in the months of April-May with a small interruption of 2-3 days only. The rapid increase of temperature and the corresponding decrease of relative humidity from 60-70% to 15-25% greatly influence the growth, as may easily be observed on trees grown under *adverse* ecological conditions.

5) The inner false rings so frequently counted by OPPENHEIMER in his one year's studies puzzled me considerably.

As for myself, I have seldom met inner false rings though many borings and transverse sections of much older trees have been examined. If, as I think, OPPENHEIMER considers as false rings the alternating layers of smaller and larger tracheids of the same year's ring, which can be distinguished in Aleppo-pine when examined under the microscope, then it must be said, they have nothing to do with false rings in their real sense as understood by anatomists and by tree ring analysers.

6) In his paper OPPENHEIMER insists on defining fixed calendar dates during which early or late wood is formed. These dates may apply only to the trees examined by him and only for the one season of his testing. But taking into account the short period of his studies, the exceptionally good ecological conditions of the trees tested and their young age, his results cannot be generalised for Aleppo pines. The distribution of rains and the constellation of all the other factors affecting growth are changing from year to year. For instance, I would not fix for the year 1917/18 the same months for early and late wood formation as for 1916/17 or 1931/32. During the former year rains continued until June. In March of that year 16 rainy days occurred with an amount of 167.7 mm. rain fall as against 9.2 mm. only during the same month in 1932.

I shall be pleased to place at OPPENHEIMER's disposition the material available at present in the Forest Research Laboratory showing the differences in width and the structure of the 2 rings between the respective 2 years. These differences are very significant.

I therefore emphasized in my paper the importance of rain distribution with regard to the time of wood formation, and this seems preferable to the stating definite dates, as is done by OPPENHEIMER.

7) OPPENHEIMER's suspicion "that etiology of growth rings can be designed" only by physiological methods which "enable to know the inner correlation regulating the growth processes in the various organs of the trees" is entirely unfounded. As against his study not exceeding one year on a few trees we have to take into account the results obtained by workers such as DOUGLASS and his collaborators, who studied these problems for nearly 40 years on hundreds of trees, testing systematically the yearly climatic variations in correlation with the tree ring structure. The results of DOUGLASS, particularly those relating to the chronology of precipitation constructed by him for 3200 years are not only eagerly used by the climatologists, but also by hydrologists and archeologists. In his studies DOUGLASS, who is an astronomer, did not apply physiological methods but created a special method of his own for such problems by crossdating the results of individual trees and by comparing their structure and width in relation to seasonal changes in climatic conditions; and after more than a million rings have been made in Tucson University, SHULMAN (13) writes in 1941: ...In the study of very nearly a million rings at the Tree-Ring Laboratory at Tucson the principles of *selection, cross-dating, and sensitivity have been the guides*".

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A GROWTH STUDY OF THE JAFFA ORANGE*)

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A. INTRODUCTION.

The growth of oranges was measured by OPPENHEIMER and ELZE (17) during the summer of 1939 in connection with their experiments on physiological indicators as guides for the proper timing of irrigations. With the same object during the years 1935-1937 measurements were performed first by Mrs. WALLENSTEIN - DE BEER, and afterwards by ELZE in the scheme of irrigation experiments arranged by SHEPHERD, GOLDSCHMIDT and OPPENHEIM (21). A first note on the results of these measurements has already been published (4).

In the 1939 experiments it was found that — apart from apparent growth reactions caused by changes in the amount of available moisture — the average daily growth in volume was nearly constant during the major part of the growth period. The same holds true for the still unpublished experiments of 1935-1937. The average daily growth in circumference, however, was largest in the beginning of the growth period, diminishing later on. In 1939 the fruit was measured from the 4th of June till the end of the irrigation period on the 15th of October, and a constant average daily growth in volume of about 2 cc. was found. Also in 1935-1937 the measurements were started at the beginning of June. They were continued until about the 10th of January, when growth diminished to such a degree that further measuring was not thought necessary. Only in the 1937-1938 season was a small number of fruits measured for a last time on the 17th February 1938, and it was found that a further average growth in circumference of 7.7 mm. had taken place from the date of the previous record on the 30th December, i.e. over a period of 49 days. In these experiments it was also found that during the first part of the rainy period the average daily growth in volume remained at about the same level as during the irrigation period; growth diminished quickly only with the onset of heavier rains and generally was insignificant already in the first week of January.

While the curve for the growth in circumference resembled a logarithmic curve, the curve for the growth in volume that could be derived from these experiments resembled the sigmoid curves obtained by other authors from similar growth studies. Only the first part of such curves, representing initial fruit growth taking place at a low rate is lacking. At the suggestion of DR. H. R. OPPENHEIMER, the present

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author therefore took additional measurements in order to collect sufficient data for the construction of a more complete growth curve. For that purpose the measurements were commenced as early as possible, and it was planned to continue them periodically, as long as any growth was perceptible.

B. REVIEW OF LITERATURE.

The growth of fruits and other parts of plants has been studied by different authors in recent years. Especially Reed (18, 19, 20) has studied the growth rate from a mathematical standpoint. In most cases, as for pear shoots and *Juglans nigra* trees (18), he found a curve that corresponds to the curve of an autocatalytic reaction: a sigmoid curve, that can be expressed mathematically by the differential equation $\frac{dx}{dt}=Kx(a-x)$, in which x is the size of the organism or organ at the time t, and a its size when fully grown. In other cases Reed (19) obtained a logarithmic curve which is also found in many physico-chemical processes, and which can be expressed by the differential equation $\frac{dx}{dt}=K(a-x)$.

Reed does not explain why the formula $\frac{dx}{dt}=K(a-x)$ should apply for the growth of apricot shoots, i.e.: that at any time the growth rate is proportional only to the growth that is still lacking before growth ceases; while for pear shoots, walnut trees and maize the formula $\frac{dx}{dt}=Kx(a-x)$ is more suitable, i.e. that at any given time the growth rate is proportional to that fraction of the total growth that is yet unaccomplished, as well as to that fraction which has already been completed. This seems rather a fundamental difference between two comparable phenomena such as the growth of shoots of apricot and of pear trees. But in a third study (20), also on apricot shoots, Reed first considers total growth during the year to be composed of 3 growth periods during each of which growth rate could be expressed by the equation $\frac{dx}{dt}=Kx(a-x)$. Concluding, however, that "...it is not entirely satisfactory to dissect a process which is undoubtably homogenous in its nature", without justifying this supposition he again uses the equation $\frac{dx}{dt}=K(a-x)$ to express the growth rate during the total growth period and its integral form to represent the growth $x=a(1-e^{-kt})$. Finding some regularly arranged deviations of the calculated growth from the observed growth, he considers that the growth in that case proceeds as if it were governed by two consecutive reactions, one of which first accelerates and later retards the other. The result is a rather complicated equation for the growth, based on the above mentioned integral. From this it would appear as if the use of the one or the other of the basic equations is influenced as much by theoretical considerations conceived before hand as by the character of the curve derived from the experimental results.

SIDERIS and KRAUS (22) also give a mathematical expression to their measurements of pineapple growth. For the growth in weight of the whole fruit, as well as of the different parts of the fruit they found sigmoid curves which correspond well with the equation used by them, a somewhat modified integral of the differential equation $\frac{dx}{dt}=Kx(a-x)$. Sigmoid curves were also found to express adequately the growth of dates. Thus such a relationship was found for their growth in fresh weight by ALDRICH and CRAWFORD (3), for the growth of their long and short axes by ALBERT and HILGEMAN (1) and by CRAWFORD (8). These authors moreover found shrinkage of the fruit to take place when it was fully ripe.

The growth of stone fruits has been thoroughly studied by a number of American authors, such as LILLELAND (11, 12, 13, 14), TUKEY (23, 24), a.o. In agreement with CONNERS (7), they found that the growth of these fruits varies considerably with time, so that 3 periods can be distinguished : a first period of accelerated growth ; a second period of no or hardly any growth and a third period of renewed accelerated growth. TUKEY (24), in measuring sour cherries, found essentially the same curves for the growth of the 3 axes as well as for the growth of the volume (determined by water replacement). Though these authors made no mathematical calculations, it seems that these growth curves are composed of 2 sigmoid curves, — one for the first period, the second for the third period, — connected by a more or less extended horizontal or nearly horizontal part symbolizing the second period. BROOKS (6) measuring the almond which he considers to be a stone-fruit of a type deviating from the previous fruits, represents the growth of the long axis and of the diameter by a simple sigmoid curve which corresponds to the fact that in almonds the growth of the pericarp can be neglected, while with the other stone fruits growth in the final third period is mainly determined by the accelerated growth of the fleshy pericarp.

LILLELAND (13), measuring the Climax plum, found the same periodicity in the growth of the diameter though less pronounced than in the other stone fruits. In the curve for the growth in volume or weight of the Climax plum, however, this periodicity was entirely absent. The author explains this phenomenon by pointing out that the shape of the plum does not remain constant during its growth, and in the course of time the long axis becomes relatively shorter.

Other fruit has been measured mainly in connection with the problem of water requirement. ALDRICH (2) studying volume of pears found an ever increasing growth rate during the summer. With a winter variety he found the growth rate diminishing after August. He does not indicate how the measurements were performed, nor is any explanation given of this rather extra-ordinary phenomenon, the interpretation of which apparently was beyond the scope of his study. With apples FURR and MAGNESS (9) found that the growth rate in

volume as calculated from the circumference — considering the apple as a sphere — was constant during nearly the whole growing period. With a summer variety the growth rate was smaller only at the beginning of the experiments, while a late variety moreover showed a smaller growth rate at the end of the season at falling temperatures. The graphical representation consequently yielded a sigmoid curve.

A large number of citrus fruit has been measured by Furr and Taylor (10) who studied lemons. Their curves show that the growth rate in volume is constant as long as enough water is available. In cases where fruit was also measured in the younger stages, a period of smaller growth was prevalent as long as the average volume remained below 10-20 cc. No reduction in growth is as a rule visible at the end; possibly because the measurements were discontinued too early to show this.

C. EXPERIMENTAL.

As in the former cases the experiments were carried out with the Jaffa orange (Shamouti). The experimental trees formed part of the groves of the Rehovot Research Station, though not the same grove was used where fruit growth was studied in 1939. The trees were planted in 1933, and budded in 1934. Most of the trees yielded a rather poor crop, resulting in coarse fruit. The measurements were performed between 8 and 9 a.m., because it was found that later in the day the results are influenced by the increasing transpiration, though no extensive study of this phenomenon was made. In the early stages the fruit was measured twice a week, afterwards once a week as far as feasible. The measurements began as early as the 12th of May. As at that date the fruit is too small to be measured with a tape — the blossom period falling into the second half of March and the first half of April — a simple caliper was used by means of which the larger cross diameter was measured. Thus the short axis of the Shamouti fruit was determined considering this as an ellipsoid, with two equal short axes, the long axis running from stem to blossom end.

Assuming that the circumference measured at the height of the short axes of the Shamouti orange, is circular, it can easily be calculated from the diameter by aid of the formula: $C=\pi D$. However measuring with the caliper is less exact than with the tape. When in July the fruit became too large to be measured with the caliper used before and this was to be replaced by a tape, both means were used side by side on July 12th. On that date the average circumference, as measured by tape, was 162 mm., while the average circumference as calculated from the caliper readings was 160 mm., with an average difference between both of 2.3 ± 0.47 mm. Though this difference is significant, we feel justified to neglect it because it had no influence on the general course of the curve of growth. This was confirmed in the next season, when with 20 fruits of the same

trees measured with caliper and tape on the 17th, 20th and 24th of June we found mean differences of 1.55±0.25 mm., 1.0±0.42 mm. and 1.45±0.52 mm. respectively. When, however, we compare the growth in circumference based on direct measurements with that based on calculation, we find differences to be negligible; e.g., for the period from 17th to 20th June, 0.50±0.44 mm. and for the period from 20th to 24th June, 0.4±0.35 mm.

The volume was calculated from the circumference according to the formula $V=0.01857\ C^3$, in which V is the volume and C is the circumference. This formula was calculated by Eng. M. Goldschmidt in connection with the measurements during the years 1935-37, on the assumption that the shape of the Jaffa orange can be considered to be an ellipsoid of which the small axis — i.e. the diameter of the circle represented by the measured circumference —, measures 91 per cent of the long axis. This relation was found to represent an average of measurements performed by Oppenheim and Elze (16) on picked fruit(1). In July 1944, 89 oranges were picked on the same trees as used in 1943 in order to find out to what degree the use of this formula is justified. Their volume was calculated from their circumference and was also measured by water replacement. The average volume measured was 96.5 cc. as against a calculated volume of 95.3 cc., with a difference of 1.2±0.45 cc. Though the difference is significant, it is so small that the agreement may be considered as sufficient. As already young fruit is found to be ellipsoid in shape, and the present study showed that the formula $V=0.01857\ C^3$, based on measurements of fully ripe fruit picked in February and March can be applied to growing fruit as early as July, we may assume that the shape of the Jaffa orange is fairly constant during the whole growing period.

A difficulty encountered in the determination of the growth of young fruit was the phenomenon known as June drop. During the experiments of 1935-37 it was found possible to begin measurements about the beginning of June without being troubled too much by fruit drop, i.e. it appeared that in Palestine the main period of fruit

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(1) The general formula of the volume of an ellipsoid, used by Eng. Goldschmidt is $V={}^4/_3\pi(\frac{1}{2}a)(\frac{1}{2}b)(\frac{1}{2}c)$ (I)

With the Shamouti orange is a the long axis between stem and blossom ends, b=c=diameter of the measured circumferential circle C.

So $b=\frac{C}{\pi}$ (II)

and also $b=\frac{91}{100}a$, or $a=\frac{100}{91}b=\frac{100}{91}\times\frac{C}{\pi}$ (III)

By substitution of (II) and (III) for a, b, and c in formula (I), we obtain:

$$V={}^4/_3\pi\times\tfrac{1}{8}\times\frac{100}{91}\cdot\frac{C}{\pi}\times\frac{C}{\pi}\times\frac{C}{\pi}=\frac{100}{6\times91\times\pi^2}\ C^3=0.01857\ C^3.$$

shedding occurs in May. Of about 200 fruits marked in May 1943, there finally remained 43 oranges of which the measurements had been started on May 20th. This fruit could be measured up to December 19th. Then a part of the fruit was stolen so that it was impossible to make reliable calculations for plotting the last part of the growth curve. However, measurements were continued on remaining fruit to obtain at least an idea of the rate of growth during the months of heaviest rain, and of the date when the growth ceased. For that purpose it was necessary to replace missing fruits as far as possible. Care was taken that these newly chosen fruits were of much the same size as the missing ones. By interpolating the obtained results on the base of the last reliable measurements, on December, 19th, we endeavoured to determine the probable course of the curve after that date. Nevertheless it remained impossible for the above reason to determine the mathematical expression of the growth curve of the Shamouti orange, as originally planned.

The results are presented in tables 1, 2 and 3, and in figs. 1, 2 and 3. Curves of the total growth in circumference and in volume,

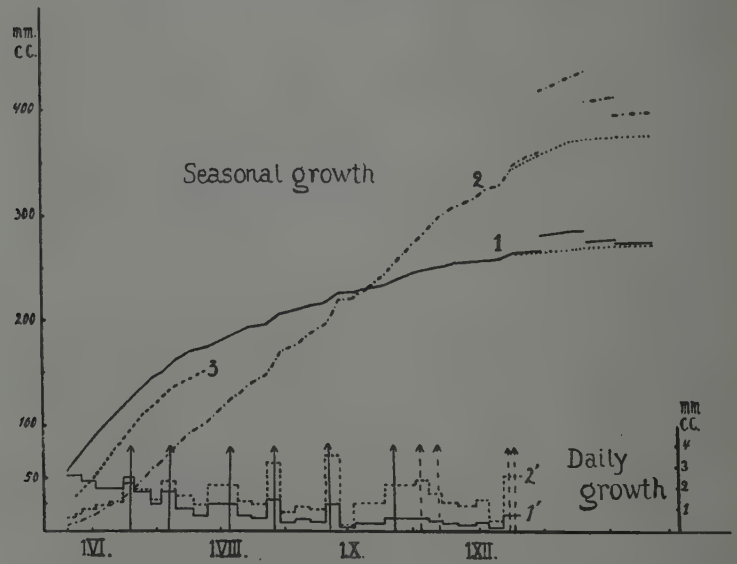

Fig. 1. 1 : Average growth in circumference of Shamouti (Jaffa) oranges during the season 1943; 2 : average growth in volume of the same oranges. The calculated growth after 19th December is represented by dotted lines. 3 : Average growth in circumferenc of young oranges in spring 1945. 1' and 2' : average daily growth in circumference and in volume of the fruits measured in 1943.
(Ordinary arrows indicate date of irrigation, broken line arrows date of rain.)

TABLE 1.

Growth in circumference and volume of 43 Jaffa oranges during the period of May 20th — December 19th, 1943.

Date	Circumference (mm)	Growth (mm)	Daily growth rate	Volume (cc)	Growth (cc)	Daily growth rate	Average temp. (°C)	Remarks
20.5	56			3.84				
24.5	66	9.5±0.5	2.4	6.10	2.26	0.57	20.6	
27.5	74	8.3±0.4	2.8	8.55	2.45	0.82	20.4	
31.5	84	10.0±0.4	2.5	12.37	3.82	0.96	20.6	
3.6	91	7.2±0.3	2.4	15.64	3.27	1.09	20.0	
7.6	99	8.0±0.3	2.0	19.89	4.25	1.07	24.2	5-6/6 khamsin
10.6	104	4.5±0.4	1.5	22.72	2.83	0.94	21.6	
16.6	115	11.8±0.6	2.0	31.35	8.63	1.44	22.5	
22.6	130	14.7±0.7	2.5	44.46	13.11	2.19	23.6	20/6 irrigated
30.6	144	13.7±0.4	1.7	59.25	14.79	1.85	23.9	
5.7	150	5.9±0.4	1.2	66.43	7.18	1.44	25.1	8/7 irrigated
12.7	162	12.2±0.5	1.7	82.95	16.52	2.36	26.1	9/7 khamsin
19.7	169	6.8±0.2	1.0	93.40	10.45	1.49	25.1	18-19/7 khamsin
26.7	173	4.4±0.3	0.6	101.07	7.67	1.10	25.6	31/7 khamsin
9.8	188	15.3±0.7	1.1	130.75	29.68	2.12	26.5	5/8 irrigated
16.8	193	4.1±0.3	0.6	139.58	8.83	1.26	26.7	9-10 khamsin
23.8	196	3.4±0.3	0.5	147.44	7.86	1.12	27.3	
30.8	206	10.1±0.6	1.4	169.92	22.48	3.21	26.9	25/8 irrigated
6.9	209	2.4±0.2	0.3	175.73	5.81	0.83	26.7	
13.9	214	4.0±0.2	0.5	188.70	12.97	1.39	26.4	8/9 khamsin
20.9	217	2.7±0.2	0.4	195.84	7.14	1.02	25.6	15-17/9 khamsin
27.9	226	8.8±0.5	1.3	219.57	23.70	3.39	24.8	24/9 irrigated
4.10	226	0.5±0.3	0.07	220.81	1.27	0.18	29.7	29/9-4/10 khams.
11.10	229	3.1±0.2	0.4	230.01	9.20	1.31	27.1	10/10 khamsin
18.10	232	3.0±0.2	0.4	239.17	9.16	1.31	25.7	14-17/10 khams.
27.10	239	6.5±0.2	0.7	259.32	20.15	2.24	23.8	25/10 irrigated
2.11	243	3.9±0.2	0.6	272.18	12.86	2.14	22.3	29-30/10 khams.
8.11	247	4.1±0.2	0.7	285.99	13.81	2.31	22.0	4-5/11 17 mm rain
15.11	250	3.2±0.2	0.5	297.31	11.32	1.62	23.5	9-14/11 khams.
22.11	253	2.5±0.1	0.4	306.30	8.99	1.28	20.4	15/11 6 mm rain
29.11	255	2.2±0.1	0.3	314.24	7.94	1.13	21.4	25-29/11 khams.
6.12	258	2.8±0.1	0.4	324.73	10.49	1.50	18.8	
13.12	258	0.8±0.1	0.1	327.87	3.14	0.45	18.4	9-14/12 khams.
19.12	263	4.2±0.2	0.7	344.22	16.35	2.73	17.5	15-20/12 72 mm rain.

TABLE 2.

Growth in circumference and volume of Jaffa oranges during the period between December 19th, 1943 and February 21st, 1944.

Date	No. of fruits	Circumference (mm)	Growth (mm)	Daily growth rate	Volume (cc)	Growth (cc)	Daily growth rate	Average temp. (°C)	Remarks
19.12'43	27	263			346.18				24//12 7 mm rain
27.12'43	27	265	2.0	0.25	356.18	10.00	1.25	16.8	25-29/12 khams.
2.1 '44	27	266	1.1	0.18	360.61	4.34	0.74	16.4	31/12 2 mm rain
2.1 '44	15	281			417.76				
17.1	15	284	3	0.20	431.01	13.25	0.88	14.8	3-15/1 117mm rain
23.1	15	284	0	0	435.20	4.19	0.70	11.3	20-22/1 48mm rain
23.1	22	277			408.41				
3.2	22	278	1	0.08	412.76	4.35	0.31	12.0	25-31/1 70mm rain
3.2	25	274			396.76				
21.2	25	274	0	0	398.71	1.95	0.11	15.0	20mm rain & khams.

TABLE 3.

Growth in circumference and volume of 20 Jaffa oranges during the period from May 24th till July 17th, 1945.

Date	Circumference (mm)	Growth (mm)	Daily growth rate	Volume (cc)	Growth (cc)	Daily growth rate	Average temp. (°C)	Remarks
24.5	31			0.63				
29.5	41	10.0±0.9	2.0	1.49	0.86	0.17	24.3	25-27/5 much dew
1.6	47	6.1±0.6	2.0	2.30	0.75	0.25	24.8	28-29.5 khamsin
7.6	63	15.8±1.1	2.6	5.48	3.18	0.53	23.3	4-5/6 irrigated
11.6	73	9.9±0.7	2.5	8.37	2.89	0.72	23.2	9/6 khamsin
14.6	81	7.7±0.3	2.6	11.14	2.77	0.92	22.6	
17.6	88	7.0±0.1	2.3	14.17	3.04	1.01	24.0	
20.6	96	8.2±0.4	2.7	18.25	4.07	1.36	24.0	22/6 irrigated
24.6	104	8.2±0.6	2.05	23.15	4.90	1.23	24.0	
27.6	111	6.0±0.3	2.0	28.10	5.06	1.69	24.4	25/6 khamsin
1.7	118	6.6±0.3	1.65	33.19	5.09	1.27	25.2	
9.7	133	14.5±0.5	1.8	46.21	13.02	1.63	25.3	6-7/7 irrigated
17.7	141	8.3±0.4	1.0	54.93	8.73	1.09	26.9	10-11/7 khamsin
24.7	150	8.6±0.4	1.2	65.19	10.25	1.46	26.2	20-24/7 irrigated
31.7	160	10.0±0.3	1.4	78.50	13.32	1.90	27.1	30/7 khamsin
7.8	165	5.5±04	0.8	86.80	8.29	1.18	27.3	4/8 khamsin

as well as curves of the daily growth rate of both appear in the diagram. The curves are reliable up to the 19th of December only. We wish to emphasize that the average growth as noted in the tables is not the difference of the average circumference or volume, but is the average of the individual differences of two measurements of circumference or volume resp. From these differences the standard errors have been calculated. But this has been done for the growth in circumference only, because the growth in volume is more markedly influenced by the size of the oranges. In respect of growth in volume the standard error would be valuable only, if the number of fruit measured was large enough to justify the assumption that all fruit sizes were sampled in accordance with the natural frequencies of their occurrence in the grove.

In their study on growth of cherry fruit, LILLELAND and NEWSOME (14) emphasized the danger of depending upon averages, while disregarding individual growth curves. Comparing the growth of individual fruits they found not only that these failed to enter the second growth period (that of depressed growth) at the same date, but also that the duration of the second period could differ considerably. In this way it may occur that, if the number of fruit measured is not large, a growth curve based on average growth will not show the sharply marked transitions of the growth periods. In the present study the small standard errors of the average growth in circumference (see table 1 and 3) demonstrate that such a divergence between the measured individuals is not probable. In fact, in this study as well as in the former ones, it could be observed that generally speaking all fruit on the trees of one plot are found to increase or reduce the pace of their growth at the same time (Figs. 2 and 3). The differences between the individual fruits consist in the intensity of the growth process: some individuals growing nearly always less, resulting in small fruits; others growing more, producing the larger ones.

D. DISCUSSION.

From the curves and the table 1 we learn that the daily growth rate of the circumference was largest at the beginning of the growth period, when it amounted to 2.4—2.8 mm; it then diminished rather quickly till the third decade of July, being 0.6 mm. between July 19th and 26th. Thereafter the growth rate slackened down gradually to about 0.4 mm., with a small rise to about 0.7 mm., probably produced by increased turgidity, during the period of the first important rain (2.6 mm. of rain were recorded on Oct. 26th, 17 mm. on Nov. 4th), until the daily growth rate at the end of December is very small; viz. 0.25 mm. or less. The curve of the growth in circumference, therefore, seems to be logarithmic and the growth rate, $\frac{dx}{dt} = K(a-x)$, seems to be proportional solely to the growth that is still lacking. The growth rate of volume, however, is still small in May, amounting to 0.58 cc per day during the period of May 20th—24th, then rising quickly and remaining at an average of 1.70 cc. during the whole

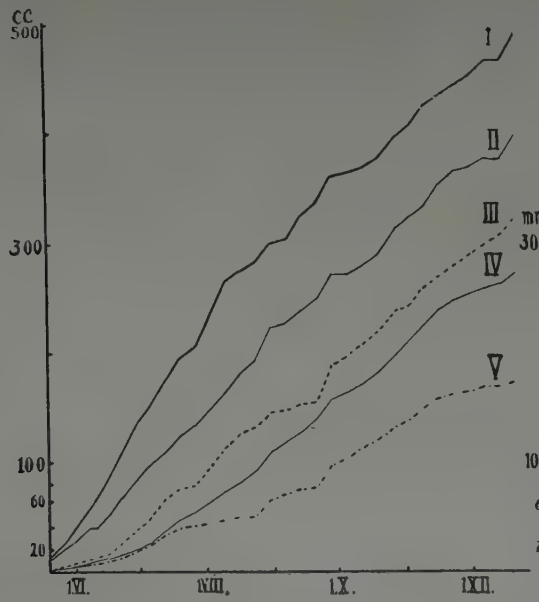

Fig. 2. I—V: growth in volume of 5 individual oranges measured in 1943.

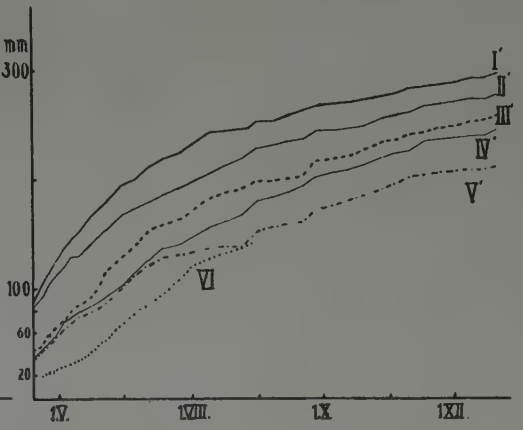

Fig. 3. I'—V': growth in circumference of the same oranges as in fig. 2. VI: growth in circumference of the smallest fruit measured in 1945.

irrigation period from June 16th to Nov. 2nd. The principal deviations are caused by pronounced changes in soil moisture such as occur before and after delayed irrigations and by pronounced diminution in air humidity brought about by dry winds (khamsins), as already stated in an earlier paper (17). Even during the first part of the rainy period, up to December 19th, the rate of growth in volume remained approximately constant; the principal deviation occurred in the week from the 6th—13th Dec. in a period of drought, when the average daily growth fell to 0.45 cc. only, followed by a rise to 2.70 cc. during the period of Dec. the 13th—19th, when heavy rains fell. Thereafter, as already stated, it was impossible to obtain exact results. But in the period from Dec. the 19th—27th (see table 2), the average daily growth of 27 oranges measured on both dates was 1.25 cc., while the average daily growth of the same fruits in the period from Dec. 27th to Jan. 2nd was 0.74 cc. The average daily growth of 15 oranges measured on January 2nd, 17th, and 23rd was 0.80 cc. and 0.71 cc. respectively, and that of 22 oranges measured on Jan. 23rd and Febr. 3rd was 0.40 cc., and that of 25 oranges measured on Febr. 3rd. and 21st was only 0.11 cc. After that date most fruits still present practically ceased to grow; shrinkage was not observed.

Though it was not possible to plot a complete reliable curve with the growth rates found after Dec. 19th, it is clear from the figures actually measured as well as from those calculated in the way as described on p. 32 (see table 4) that the growth curve of volume is of a sigmoid type. This implies that the growth rate at any given time is influenced by the amount of growth still lacking before the ultimate size is attained, as well as by the growth that has already been completed at that time. In the case a pure sigmoid curve is achieved, is growth rate $\frac{dx}{dt} = Kx(a-x)$.

TABLE 4.

Hypothetical average growth of Jaffa oranges calculated from the average growth in table 2 by interpolating on the basis of the last reliable measurements on Dec. the 19th.

Date	Average calculated circumference	Average growth	Daily growth rate	Average calculated volume	Average growth	Daily growth rate
19.12	263	—	—	344	—	—
27.12	265	2	0.25	354	10	1.25
2.1.'44	266	1	0.18	358	4	0.67
2.1.'44	266	—	—	358	—	—
17.1	268	2	0.13	369	11	0.73
23.1	268	0	0	372	3	0.5
23.1	268	—	—	372	—	—
3.2	269	0.7	0.06	374	2	0.17
3.2	269	—	—	374	—	—
21.2	269	0	0	375	1	0.09

We are here confronted with the phenomenon that the changes of growth rate in volume in the course of the season and those of growth rate in circumference of the same fruit are governed by different mathematical laws. In other cases where the linear and volumic growth of the same object were measured, it was found that the two are governed by the same law. In most cases a pair of curves of the sigmoid type was found, e.g. by Tukey (23) for the growth of the 3 axes and of the volume of the sour cherry, by Lilleland (11) for the growth of the diameter and of the weight of the apricot. (Here the weight, being proportional to the volume, can be considered as a measure of volume). As regards the growth of the date, the same type of curves was established: by Albert and Hilgeman (1) and by Crawford (8) who measured the long axis and the diameter, and by Aldrich and Crawford (3) who measured the fresh weight. The difference between the growth curve of the diameter and those of the volume and the weight as determined by Lilleland (13) for the Climax plum, could be readily explained by the changes in form of the fruit during the growth process. As already discussed (see p. 31) such a change in form did not occur in the Jaffa orange. It seems that with plants rarely both the growth in linear dimensions and in volume follow the course of logarithmic functions. (Reed (18) in calculating the measurements of the height and weight of growing cows, found such a curve to apply for both).

An explanation of this phenomenon of different types of curves for the growth in circumference and in volume as reported here, is not easily furnished. In accordance with the equation $V=KC^3$ the growth rate in volume (implying changes in the third power of linear dimensions in contrast to girth) may well be imagined to be more markedly influenced by the amount of growth already accomplished than in the case where the growth rate in circumference is concerned. For this reason the former may be expected to conform more frequently than the latter to a sigmoid curve. But in the studies of fruit growth already cited, e.g. those of ananas, dates and cherries, growth in circumference proceeded according to a sigmoid curve just like the growth in volume and in these cases the two curves were largely parallel. Thus the possibility could not be eliminated that in the present study the measurements were only begun when it was too late to show that period of slow growth of the circumference which can be represented by the beginning of a sigmoid curve. It was therefore decided to repeat in 1945 the measurements of young fruit as early as possible after the bloom. Because of pruning and of the drop of nearly all the fruits first chosen, the measurements were nevertheless delayed. But because the flowering season was rather late that year, and by choosing fruits resulting from the latest flowers of the season, it was possible to start with twenty fruits with an average circumference of 31 ± 1.4 mm. as against 56 ± 2.0 mm. in the previous measurements. The average daily growth rates in circumference during the first periods meas-

ured (see table 3) was 2.0 mm. during five days, 2.0 mm. during three days, 2.6 mm. during six days, 2.5 mm. during four days, 2.8 mm. during three days, 2.3 mm. during three days, 2.7 mm. during three days, 2.1 mm. during four days, 2.0 mm. during three days respectively as against records of 2.4; 2.8; 2.5; 2.4; 2.0; 1.5 mm. during nearly the same period of 1943. Though there is some indication that the fruit is starting with a small daily growth, followed by a short period of larger daily growth which again is followed by gradually diminishing daily growth, it cannot be denied that these indications are very feable (see also curve 3 fig. 1). More pronounced is the sigmoid course in the curve of a single small fruit (fig. 3 curve VI). Also in regard to the growth in volume is the sigmoid course clearer in smaller (and younger?) fruits than in larger ones (fig. 2). Moreover if on account of these figures it should be concluded that also the growth in circumference of the Jaffa orange can be represented by a sigmoid curve, the fact remains that the course of this curve differs greatly from that of the curve for the growth in volume of the same orange. The former has only a short period of constant growth followed by a long period of diminishing growth beginning in the last week of June, while the latter is characterized by a long period of constant growth changing to a period of diminishing growth only when the heavy rains start. However, though one may consider both as sigmoid curves, neither the curve for the growth in circumference, nor that for the growth in volume are similar in shape to the sigmoid curve that results from an autocatalytic reaction, such as found by REED (18) in measuring tree shoots, and it may be doubted whether the formula $\frac{dx}{dt} = Kx(a-x)$ is applicable to them. In fact, it may be questioned whether the resemblance found between the rate of progress of as complex a phenomenon as the growth of higher plants and that of an autocatalytic reaction is more than accidental.

In a discussion on the subject with Dr. OPPENHEIMER we arrived at the conclusion that from a physiological standpoint it may *a priori* be expected that in young fruits the afflux of plastic material is limited by the relatively small number of sieve tubes, while cells which are ready to divide and grow in volume are also scarce. This may be expected to result in a low growth rate. Later on, a growing number of conductive elements will be present and also more cells will take part in the formation of new tissue and its growth. In this way the fruit will be able to grow at an accelerated pace which, however, soon again will become limited by the restricted supply of plastic food. After establishment of an equilibrium between food supply and use by the growing tissue, growth in volume may be expected to become constant. When the fruit is nearly fully grown, it is quite understandable that the growth rate decreases again, probably by lack of growth hormones. Thus at the end of the season a period of diminishing growth rate is brought about, and the whole process of growth corresponds more or less to a sigmoid curve.

It is remarkable, however, that the growth in circumference seems not to be affected so much by these physiological factors. At a moment when the rate of growth in volume is still low, the rate of growth in circumference already has reached its maximum and will decline considerably during the following month. The rate of growth in volume will have reached its maximum only at that time while from that moment the latter remains nearly constant, the former will continue to decline, though more slowly.

The curve of growth in volume of the apple as established by Furr and Magness (9) shows much resemblance with that of the orange, i.e. 1) a short period of slow growth, 2) a period of constant growth covering the major part of the growth season, and, with a winter variety, towards the end of the growth season again 3) a short period of slow growth. It would be of interest to know whether the similarity in growth of the two fruits goes so far that with the apple records of growth in circumference also yield a curve of the logarithmic type.

No indications of periodicity were found in the shape of the curves, at any rate no periodicity that can be connected with the periodicity of shoot growth. Also Lilleland (12) states that no connection was perceptible between the periodicity of growth of the peach fruit and the growth of its shoots.

In conclusion we wish to mention the remarkable fact that the oranges continue to grow during the major part of the winter, even during the 2 coldest months of the year, viz. January and February (see table 2). Part of this growth may be apparent only and connected with rising water content, sucked into the fruit by a raised osmotic suction power of the endocarp cells which, in its turn, is a consequence of the rising percentage of soluble solids in the juice, as stated for the Jaffa orange by Braverman and Carmi (5). Possibly this growth is to a certain degree caused by afflux of additional organic material, but this cannot be proved by measurements of that kind, as is shown by Lott (15) for the peach and by Aldrich and Crawford (3) for the date. They found that growth in dry weight not always runs parallel with growth in fresh weight (or volume) and diameter. But for a growth study on dry weight basis much more material and work would have been necessary; in the present study no experimental base exists for reasoning about this subject.

E. SUMMARY.

The article reviews some studies of growth in length or in volume of parts of plants, especially of fruits. Special attention is paid to Reed's mathematical considerations concerning growth of shoots of some fruit trees.

Reed expresses the studied growth phenomena by the equations $\frac{dx}{dt}=k(a-x)$ or $\frac{dx}{dt}=kx(a-x)$. The former equation rendering a logar-

ithmic curve, also suits many physico-chemical processes; the latter, rendering a sigmoid curve, fits autocatalytic processes.

It is pointed out that it is not always possible to interpret the results of the experiments so exactly as to ensure a definite growth curve. In such cases the two formulae may be used alternatively for the same series of growth measurements, though it may be necessary to use modifications in order to obtain a closer correspondence. The choice of the one or the other formula will be influenced by the theoretical standpoint of the investigator.

The literature on the growth of stone fruits is reviewed at some length, as well as measurements of apple, pear, and lemon which have been undertaken in connection with irrigation experiments.

In the present study it was found that the growth in circumference of the Shamouti orange suits a logarithmic curve, whereas the growth curve for volume proved to be rather of a sigmoid type. However, the latter shows — between the relatively short periods of slow growth at the beginning and at the end of the growing season — a protracted period of constant growth. Hereby it deviates greatly from a normal sigmoid curve.

In a second series of measurements of the circumference, started when the fruit was still very young, a slight indication of an initial period of slow growth was found, as is also to be expected on physiological grounds. Though the growth curve for the circumference might thus be also of the sigmoid type, it, nevertheless, differs in its general course greatly from the growth curve of volume. In studies where length (or circumference) and volume (or weight) of the same fruit have been measured by other authors, curves running nearly parallel have been found.

It is doubted if the resemblance of growth curves with the sigmoid curves of autocatalytic reactions or with the logarithmic curves of physico-chemical reactions is more than an accidental one. It is tried to give a physiological explanation of the occurrence of a sigmoid curve.

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THE GROWTH OF CITRUS ROOTS AND SHOOTS UNDER DIFFERENT CULTURAL CONDITIONS*)

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INTRODUCTION

Several authors (2, 3, 4, 17, 20) have already investigated the shoot and root growth of citrus trees. It has generally been pointed out that in the course of each year there are several periods of growth of both roots and shoots and that the periods of root growth do not in general coincide, but alternate, with periods of shoot growth. However we are not aware of publications dealing with the intensity of root and shoot growth throughout the year of trees subjected to different pruning or fertilising treatments.

The present paper is a report on such an investigation into the annual cycle of growth of citrus shoots and roots under different pruning and manurial treatments as applied for the rejuvenation of neglected orchards. Edaphic factors limiting root growth and the relation between shoot and root growth are also discussed.

SOIL AND TREES

The Z. citrus grove serves for experiments on the rejuvenation of neglected citrus trees [cf. OPPENHEIMER (14, 15)]. It is situated about 3 kms. south of Rehovot on the south-western slope of a hill. The soil is lighter on the top of the hill, getting heavier towards its foot, as usual in the coastal plain of Palestine. All the trees studied are Shamouti (Jaffa) oranges which were budded on sweet lime stock about 1933. In June, 1942, after the grove had been neglected for some years, it was divided into plots supplied with different amounts of manure and fertilisers and pruned with varying degrees of severity. Our observations were carried out on a limited number of trees representative of widely different treatments, beginning in September, 1943 and ending in September, 1944. The total number of trees investigated was 22. Of these a group of eight consisted of trees deheaded in June, 1942 at about 1.4 metres height (treatment III of the pruning scheme); by September, 1943 these had developed a beautiful top of new branches. Four of these trees were fertilized every year with 1 kg. ammonium sulphate and about 30 kgs. of sheep or mixed manure (treatment III/4), while the four others had not been fertilised for years (III/1).

*) Abridged translation of a thesis presented to the Hebrew University in 1944 for the degree of Master in Agricultural Science.

A second group of eight consisted of trees the pruning of which was restricted to a minimum, i.e. dry, dead wood only was pruned (treatment I of the pruning scheme). Four of these trees received the fertilisers mentioned above (I/4). while the four others had not been fertilised for years (I/1). A third group of six consisted of trees which had been left totally unpruned (treatment O of the pruning scheme). Four of these were fertilised as above (O/4), while the two others had not been fertilised for years (O/1).

Of the trees studied those under treatments III/4 and III/1 grow on sandy soil near the top of the hill, the others in light sandy loam lower on the slope of the hill. Table I shows the mechanical composition of two typical samples taken from the above soils at a depth of 20 to 25 cms.

TABLE I

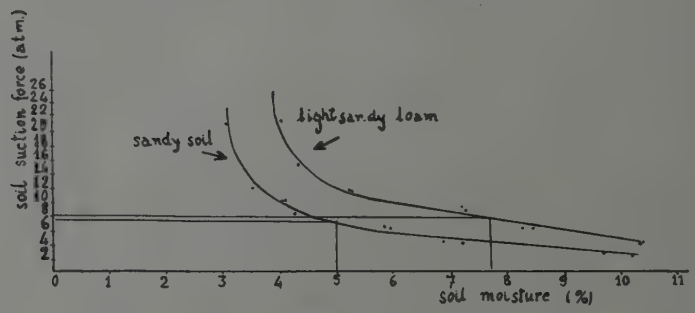
Mechanical composition of soil in the Z. grove.

Locality	*Coarse sand*	*Fine sand*	*Silt and Clay*
Top of the hill	16.0%	78.6%	5.4%
slope of the hill	12.3%	75.7%	12.0%

On the same samples determinations of the soil suction force were carried out according to procedure "b" of SCHOFIELD and BOTELHO DA COSTA (19). The results are shown in figure 1.

FIG. 1

The dependence of soil suction force upon soil moisture in the root zone of orange trees in two soil types of grove Z.



METHODS

While shoot growth can be easily studied, investigations of root growth meet with certain difficulties. Different methods have been devised by several students in this field. Some authors have dug tunnels or pits lined with boards provided with windows for root observation [ROGERS (18); WAYNICK and WALKER (20); etc.]. Others have used trees growing in water solutions [CHAPMAN and PARKER (2)], the root system of which may be inspected at any time.

We used the simplest method imaginable: digging small ditches near the tree, by means of a hoe, and examining the roots dug up. The chief drawbacks are: (1) damage is inflicted upon the roots, (2) only a small fraction of the root system may be inspected at a time. Nevertheless, if used with discretion, this method may yield valuable results.

Every fortnight, during a year, we alternatively examined half the number of trees of each group. Root and shoot growth were recorded. The ditches were dug at a distance of about 75 cm. from the trunk at one of four equidistant places. Thus we dug again at the same place only after 16 weeks. We may assume that after such long intervals abnormal alterations of the intensity of growth of fine roots, produced by the previous digging operations could no longer be of much significance. As a rule, the roots investigated were taken from a depth of 20 to 25 cms., rarely as deep as 30 or as shallow as 15 cms., i. e. from the upper of the two main root-layers of the sweet lime stock. We rarely dug as deep as 75 cms., i. e. into the second root-layer, but no considerable deviation from the intensity of growth determined in the upper layer was recorded there.

As noted already by CRIDER (4), the colour of rootlets provides us with a simple criterion to show whether citrus roots are growing or not. The typical colour of the new rootlets is white, somewhat pellucid and readily distinguishable from the yellowish-brown colour of suberized roots.

Although recent studies of CHAPMAN and PARKER (2), KRAMER (9), and HAYWARD, BLAIR and SKALING (8) have shown that roots in general and citrus roots in particular may after suberization continue to absorb water and nutrients at a considerable rate, possibly through lenticels, there is little doubt that absorption takes place chiefly by means of white growing rootlets. The number of new rootlets, as related to the total number of roots investigated, therefore constitutes a useful measure not only of the intensity of growth but also of the absorbing power of the whole root system at any given moment.

Much importance was attached to the manner of sampling, which had to be standardized as much as possible; this was done in the following way. Three lumps of soil well penetrated with roots were dug up; each bunch of roots was examined separately. For the estimation of growth intensity we preferred a scale of five marks to one of ten adopted earlier by COSSMANN (3). These marks denoted the following growth intensities:

0. — No white root tips.
1. — White tips only occasional.
2. — Only moderate new growth on relatively few ultimate ramifications of thin skeleton roots.
3. — Relatively few thin skeleton roots with white tips on the majority of their ultimate ramifications, or many thin skeleton roots with fewer white tips on their ultimate ramifications.
4. — Many thin skeleton roots with a conspicuous number of white tips on their ultimate ramifications.
5. — Most or all ultimate ramifications with white tips.

The inspection of shoot growth is much simpler, since the whole top may be inspected at one time. The size of the leaves inserted at the youngest nodes of the shoot was chosen as an indicator whether or not the growth of a given shoot is completed. On a growing citrus shoot the size of the leaves becomes progressively smaller towards the top. When growth ceases the upper leaves rapidly attain full size. A different criterion has been established in an unpublished paper of DE BEER (5). She states (and we can confirm her statement) that the youngest internode together with some leaf initials at the growing point is shed when citrus shoots stop growing*). Both criteria yielded practically identical results. As with roots, the intensity of shoot growth was estimated according to a scale of five marks:

0. — No shoot growth.
1. — Scarce shoot growth on isolated branches.
2. — Moderate shoot growth on a larger number of branches.
3. — Moderate shoot growth on most branches, or vigorous shoot growth on fairly numerous branches.
4. — Vigorous shoot growth on most branches.
5. — Very vigorous shoot growth everywhere.

Records of edaphic conditions prevailing when the growth intensity of roots and shoots were estimated were taken as follows:

1) Soil samples were taken from the tangles of roots we examined; their water content was determined by drying in an oven at 105°C., and was calculated as percentage of dry soil weight.

2) The temperature of the soil was measured in two places in the orchard at 30 cms. depth. According to observations reported by ASHBEL (1), under quite similar conditions, diurnal fluctuations of temperature at this depth which is characteristic of the upper root-layer, do no exceed 2.4°C. Records taken at any time of the day can thus be trusted to be representative of conditions prevailing during that day.

3) Rainfall and dates of irrigation were recorded.

RESULTS

Introductory remarks on shoot and root growth.

According to DE BEER (5), the growth of a single **shoot** may sometimes continue uninterruptedly for two months, but in many cases the period is much shorter. The length of the period of growth differs according to season. In the warm season the shoots grow rapidly to a considerable length, while in the cold season they grow slowly, unfolding small, light green leaves. In any case the period of growth of a single shoot lasts more than a fortnight.

In order to investigate the length of the growth period of any single **root** tip, at different seasons, white rootlets were uncovered and marked with a loose woollen thread. In order to facilitate further

*) The same was already found by OHLERT (12) to apply to several European trees such as, *Tilia, Ulmus* etc.

their recovery their tip was introduced in a natural position into a wide-necked bottle, half filled with moist soil. The bottle was then covered with at least 20 cms. of moist soil. Although it might have been preferable to avoid the use of bottles we did not gain the impression that edaphic conditions in the bottles were much different from those obtaining in the adjacent soil. In each of the cases investigated the rootlets were found suberized after a fortnight. This resembles the behaviour of apple rootlets which, according to ROGERS (18), become suberized within a period varying from a week to a month.

For each treatment, graphs**) were drawn to represent the intensity of shoot and root growth, soil temperature at the depth of 30 cms., and soil moisture. Figures of growth intensity are the averages of observations on alternating couples of trees undergoing the same treatment. This seems justified since individual differences established in simultaneous examinations of two adjacent trees amounted in most cases to not more than one half to one mark. While more frequent observations of the growth processes would have been desirable and might have rendered somewhat different results, it is also probable that the curves of soil moisture and temperature show fluctuations smaller than those which took place in reality, since no self-recording instruments were at our disposal.

Curves of soil moisture and temperature.

The curves of soil moisture and temperature strike the eye by their inverse relationship during the whole year.. The subtropical climate of Palestine with cool weather during the winter rains and high air temperatures during the dry period, accounts for this trend. During the hot season every irrigation causes some fall in soil temperature but, owing to high air temperatures and radiation, average soil temperature nevertheless increases in the course of the summer; we found this average to be about 20°C. in March and 31°C. in July and August. In consequence of this general trend, combined with the cooling effect of irrigation, the soil temperature rises during summer, step by step. Every up and down of this curve is matched by an inverse fluctuation in the soil moisture curve.

Intensity of shoot growth.

In the majority of the trees examined a period of shoot growth ended early in October, 1943. Another period of intensive shoot growth began shortly afterwards and ended only late in December. The new growth of the spring cycle burst out simultaneously in all the trees late in February, continuing with great intensity till late in April.

**) The curves of shoot and root growth, and of soil moisture and temperature during the whole year are represented in fig. 2 in a very concise manner. They have been redrawn from more detailed originals laid down in the archives of the Hebrew University.

Summer shoot growth began early in June in some trees, in others somewhat later, and sometimes had not ended at the end of our observations in September, 1944. Three well defined growth cycles have been recorded by us in the majority of the cases, and this is in agreement with investigations of authors such as REED (16), REED and MACDOUGAL (17), CHAPMAN and PARKER (2), WAYNICK and WALKER (20), and CRIDER (4).

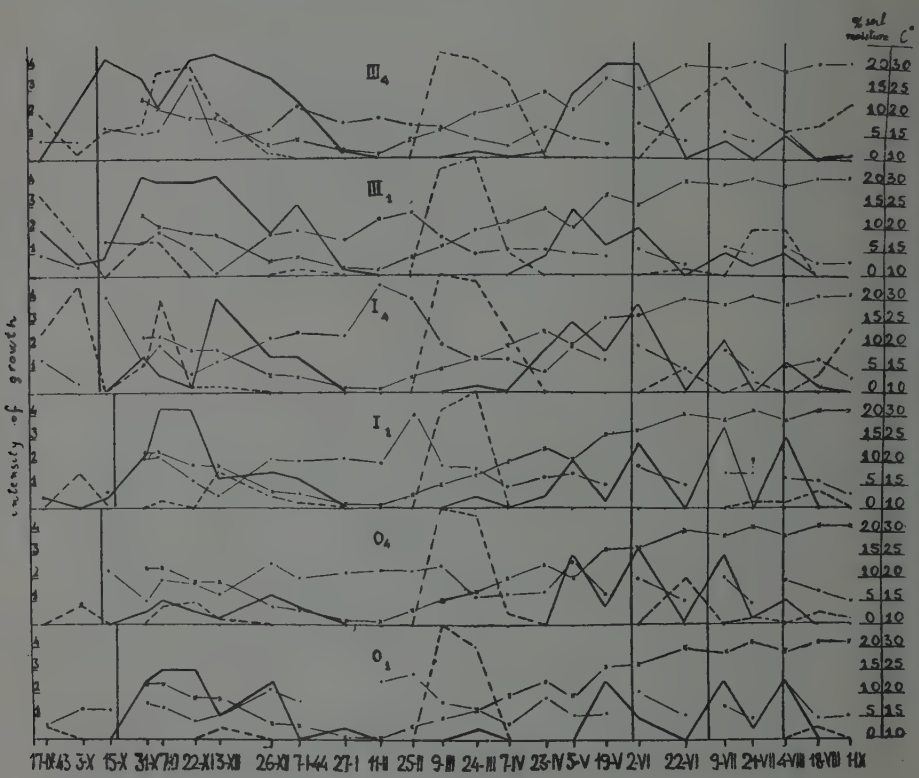


Fig. 2: Graphs showing intensity of growth of roots and shoots of Shamouti orange trees, percentage of soil moisture and soil temperature at each date of the investigation. Vertical lines indicate dates of irrigation.

intensity of shoot growth — — — —

intensity of root growth ————

•–•–•–•–• % soil moisture

×–×–×–× soil temperature

Application of manure seems in general to have increased the intensity of shoot growth in summer and fall, but its effects cannot easily be assessed in spring when all trees evinced a similarly vigorous outburst of growth.

With regard to the different pruning treatments comparatively weak growth was recorded in fall 1943 in all unmanured trees which had either been left unpruned or had been freed from dead branches only. The same is true for unpruned but manured trees, while all other combinations of treatments evinced more vigorous growth. It can therefore be stated that heavy manuring failed to increase shoot growth in neglected trees which had been left unpruned, was useful to trees which had been freed from dead branches, and exerted no pronounced effect upon deheaded trees which in any case regenerated their tops vigorously. In summer 1944, the picture was somewhat different. The favourable influence of manure was more conspicuous also in the deheaded trees and very marked in those which had been freed from dry branches only. This is in line with the results of OPPENHEIMER (14) who found that the favourable influence of manure grows more conspicuous during the second year after deheading.

In spring no relation between vigour of shoot growth and severity of pruning was apparent: all trees evinced very vigorous shoot growth.

No link between the edaphic factors studied and intensities or time of shoot growth could be found.

Intensity of root growth.

Root growth alternated in most cases with shoot growth.

A cycle of root growth was found to begin in mid-September or in early October, and to continue till late in January or early in February. Root growth remained at a very low ebb or was even nil during March and early April and burst out again in all treatments in mid-April or a little later (except O/4, where a slight delay was recorded). During the summer, fluctuations were governed by the rhythm of irrigation. No conclusions can therefore be drawn concerning the yearly number of root growth cycles.

Differences between manured and unmanured trees were still less well marked than was the case with shoot growth. While some favourable effects of manure were apparent in summer 1944, the results of fall 1943 cannot be easily explained. Actually at that time unpruned trees which had n o t been manured showed a more vigorous growth than those which had been manured. The same applied, though to a lesser extent, to trees, which had been freed from dead branches only. Misleading results may sometimes be obtained owing to the fact that root growth is, of course, more pronounced in rotted lumps of manure than in adjacent soil which may have remained free from manure if distribution was uneven. If the sample happens to be taken

in unfertilised soil, only few growing rootlets may be found while quite different a situation may prevail nearby. This aspect deserves further attention.

As to the influence on root growth of the different pruning treatments applied to the tops, only in autumn 1943 was a considerably higher relative intensity of growth found on deheaded trees or in trees which had been freed from dead branches only than on unpruned trees. In the following summer no important differences were noted to derive from the various pruning treatments.

The curve of root growth runs nearly parallel to the curve of soil moisture throughout the whole irrigation season. The diagrams show that when the water content of the soil drops below a certain limiting figure, root growth is seriously hampered or even ceases completely. This figure evidently differs for the two soils studied (samples taken on the top of the hill and on the slope, see table I).

It is not easy to establish exactly where this limit lies. A glance at the data collected in table II shows that, as would be expected, it coincides with a higher water content in the somewhat heavier soil from the slope than in that from the top of the hill. The data allow the conclusion that the moisture percentage limiting root growth is about 7.7% for the former and 5.0% for the latter soil. These percentages correspond to a soil suction force of about 7.5 to 8 atmospheres (see fig. 1).

TABLE II

Moisture percentage of soil samples as related to concomitant growth of roots during the irrigation season of 1944.

Treatments and soils	Root growth recorded: less than one mark				Root growth recorded: from 1 to 5 marks		
	22/VI.	21/VII.	18/VIII.	1/IX.	2/VI.	9/VII.	4/VIII.
I/4, slope	5.2%	4.3	7.1	3.1	9.9	9.1	5.7[1])
I/1, „	5.1	7.9[1])	6.1	3.1	8.8	7.9	6.4[1])
5/4, „	5.0	4.9	7.1	4.8	10.1	10.2	9.5
5/1, „	5.4	4.6	4.5	4.9	10.4	7.8	12.4
III/4, top	3.7	4.3	0.4(?)	1.3	7.4	6.0	6.1
III/1, „	2.5	4.8	3.8	3.2	5.6	6.5	6.6

Figures marked by [1]) bear an exceptional character as discussed in the text.

DISCUSSION

Shoot growth

The fact that no link could be found between the edaphic factors studied and intensities or time of shoot growth, as pointed out above, may lead us to infer that growth of shoots is mainly

governed by internal conditions, as indicated by HALMA (7), rather than by edaphic factors.

Root growth and external conditions.

SOIL TEMPERATURE. This is the edaphic factor limiting root growth of citrus trees in the cool season. This fact, stressed by COSSMANN (3), WAYNICK and WALKER (20), and others, is confirmed by the present investigation. Below soil temperatures of +13° or +14°C., no growth of roots has been recorded. This is in agreement with GIRTON'S (6) data showing that +12°C. is the minimum temperature of root growth of different citrus varieties in culture solutions.

According to WAYNICK and WALKER (20) differences of temperature at various depths may cause different growth intensities of roots at various levels, especially where limiting temperatures are approached. In fact, if temperature in a given layer is above, while in more superficial layers it is below, the minimum, root growth will be inhibited only in the superficial layers. Our curves, as stated above, represent fluctuations of temperature at the depth of 30 cms. while the investigated roots were in their majority found in the soil layer between 20 and 25 cms. However, according to ASHBEL (1) even the difference between average monthly temperatures at depths of 10 and 30 cms. is generally less than 1°C.

Unlike its effect in winter, soil temperature was not found to be a factor limiting root growth during the hot season. GIRTON'S (6) optimum for root growth of citrus seedlings is about 26°C., the maximum 37°C. Therefore temperatures between 26° and 31°, which prevail in Palestine from May to October in the investigated soil layer, cannot be expected to prevent root growth or to limit it to any considerable extent, especially in a variety so well adapted to hot climates as the sweet lime stock. Our diagrams bear out this fact quite clearly. Very intensive growth of roots is often linked with soil temperatures of 29°C. and more (in July and August), if soil moisture is ample; while sometimes, if soil moisture is low, scarce growth is recorded at 26°C. earlier in summer (cf. records for treatment O/4 on May 19th and July 9th, or for treatment O/1 on June 2nd and August 4th).

SOIL MOISTURE. This is the main edaphic factor limiting root growth during the irrigation season. WAYNICK and WALKER (20) and COSSMANN (3) already stated the importance of this factor, while REED and MACDOUGAL (17), who supplied their trees with a fair quantity of water (without recording, however, the fluctuations in soil moisture) did not discuss it.

As we have shown above, a soil suction force of about 7.5 to 8 atmospheres seriously hampers root growth. It seems that root growth comes to a standstill when the soil suction force is equivalent to the osmotic value of the roots, although it has recently been found

by MENDEL (10) that the transpiration of Shamouti trees is strongly reduced well before the soil suction force equals the osmotic value of the roots of the stock. Osmotic values for roots of sweet lime stock have been measured by COSSMANN (3) and were found to fluctuate between 6.9 atm. for seedlings thriving in a well moistened soil and 9.6 atm. for those suffering from shortage of water. The figure of 7.5 to 8 atm. is therefore in good agreement with previous data. Two exceptional cases are recorded in table II, where remarkably vigourous root growth occurred at soil moisture percentages lower than would be anticipated in accordance with the above assumption (August 4th, treatments I/4, I/1). The lower value (5.7%) corresponds, in the soil concerned, to about 11 atm. which is possibly still acceptable as equivalent to the osmotic value of roots under extreme conditions. Only once has growth failed to be recorded at 7.9% soil moisture (corresponding to slightly less than 8 atm.). As to the lighter soil (from the top of the hill), no exceptions from the above rule are recorded, i. e. neither has root growth been observed below, nor its absence above, 5% soil moisture. This is not unexpected since the rise in soil suction force at the critical level of 7.5 to 8 atmospheres is much more rapid in this light soil than the corresponding rise in the former, somewhat heavier soil.

Connection between shoot and root growth.

As emphasized above, the curve of intensity of root growth evinces a course roughly inverse to the curve of intensity of shoot growth. One feels inclined to seek the explanation, at least partially, in some internal factor limiting root growth while and as long as shoot growth takes place. This conclusion is supported by observations that even if soil temperature and moisture are favourable for root growth, but shoot growth is proceeding vigorously, no growth of roots takes place. This is the rule in all treatments during March and April and sometimes also during the summer flushes of growth. Similar results have been recorded in an unpublished investigation carried out by the present writer in the "root stock trial" grove [see OPPENHEIMER (13)] where the intensity of growth of shoots and roots of Shamouti trees budded on different stocks and growing under different conditions of water supply was recorded. Here one Shamouti tree budded on sweet lime furnished further evidence of interrelations between root and shoot growth. The above tree received weekly irrigations supplementary to the ordinary irrigation scheme. As the soil is deep sand, no waterlogging took place. The curve of soil suction force, as determined by MENDEL (10) for the same soil, some 100 metres distant from this tree, shows that the critical value of 8 atm. lies at about 1.75% soil moisture. Although in other comparable trees root growth was sometimes recorded at moisture values well below 2.0%, it came to a standstill in this particular tree between early June and early July, 1944, though soil temperatures were between 25° and 28° C., and the water content of the soil did not even

drop below 3.5%. It seems important to note that shoot growth was recorded at the same period. Between early July and early September, there was a period of root growth, while no shoot growth took place. Early in September, root growth was again interrupted, while shoot growth was resumed. Even immediately before the preceding irrigation (on August, 27th) was applied, soil moisture was 2.8%, i.e. quite sufficient for root growth.

It is therefore very probable that internal factors limiting root growth are in action during periods of shoot growth. These factors may be of a complex character, but inhibition by hormone-like substances is very strongly suggested by the facts. Investigations which we undertook on the base of this assumption, including attempts aimed at the interception of auxin in the living bark on its way from shoots to roots by means of agar agar slices, did not yield positive results, possibly because of the lack of a suitable technique. We were only able to demonstrate that auxin is present in growing shoots of Shamouti trees as already reported (11). Further investigations on these lines will possibly throw more light on this interesting problem.

Acknowledgments. The author is much obliged to Dr. H. R. Oppenheimer under whose guidance these investigations have been carried out. He further wishes to thank Mr. K. Mendel, M. Sc., and Dr. D. L. Elze for technical advice and helpful criticism.

SUMMARY

The intensity of growth of roots and shoots of Shamouti (Jaffa) orange trees budded on sweet lime stock under different pruning and manuring treatments has been investigated during one year.

Application of manure seems in general to have increased the intensity of shoot growth, its influence becoming more evident in summer 1944 than in autumn 1943. Previous deheading of trees also played an important role in increasing the intensity of shoot growth. All trees, irrespective of treatment, evinced very vigorous shoot growth in the spring flush.

Application of manure and severity of pruning of the tops seem to have a less pronounced influence on intensity of root growth. It has been confirmed that soil temperature during the cool, moist season and soil moisture during the hot dry season are the main external factors limiting root growth under the conditions investigated. The limiting soil temperatures are $+13^{\circ}$ to $+14^{\circ}$C., and the minimum soil moistures correspond to soil suction forces of about 7.5 to 8 atmospheres.

Shoot growth does not seem to be influenced by edaphic factors. As to the relations between shoot and root growth, which usually alternate, extensive growth of shoots seems to have a definite inhibitive action on root growth, although no definite statement can yet be made in this respect.

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EXPERIMENTS WITH DICHLORO-PHENOXY-ACETIC ACID AS A HERBICIDE

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It is well known that the destruction of monocotyledoneous weeds meets with serious difficulties, and this is found true especially in the case the weed possesses perennial root stocks. Preliminary experiments carried out by the author with 2, 4-D in concentrations ranging between 0.1 and 0.5% did not lead to the destruction of *Cynodon Dactylon, Sorghum halepense* and *Cyperus rotundus*. Satisfactory results with *Cynodon* were obtained only when this grass was sprayed with a 5% solution.

Since it was our aim to use the herbicide in citrus groves, it was considered essential first to investigate the tolerance of citrus plants to highly concentrated solutions of 2,4-D. Simultaneous experiments were undertaken in order to elucidate their influence upon seeds of cultivated annual plant species and citrus(*).

Toxic effects on seeds. Seeds of beans, peas and sweet lime were sown in pots and the soil sprayed with a 5% solution of 2,4-D. All seeds failed to germinate while sprouting normally in control pots.

Toxic effects on citrus seedlings. Equal numbers of appr. 50 cm high seedlings of sweet lime and sour orange were divided into three groups and the soil around them was sprayed with solutions of 2,4-D on each one of the following dates: March, 11th, March, 31st and June, 10th, 1947. 5 concentrations were used: 0.5; 1.0; 1.5; 2.0 and 3.0%. A number of seedlings of each species served as control: no spraying was carried out in their immediate neighbourhood. Another group of seedlings growing together with the others in the greenhouse of the division was not sprayed either, but came in contact with the herbicide by percolating irrigation water.

The acid was first dissolved in ethanol and then diluted with water to the desired strength, adding "Agronim" as a sticker. Care was taken not to spray the stems and leaves of the seedlings.

Results: The reaction of the plants varied but little according to season. 7—10 days after the treatment the leaves evinced curling or twisting which progressed from the top downwards. Two weeks after the treatment, the leaves turned yellow and wilted. In a final

*) The author wishes to acknowledge the help of Dr. A. Haskelberg, of the David Sieff Institute who synthesized the chemical and put it at his disposal.

phase, the stems dried up, beginning from the top. When one month after the spraying, the damaged plants were uprooted for examination of their subterranean parts, heavy damage, evidently of a primary nature was noted. As a rule, the root cortex was tumid or wrinkled or rotten. The xylem of heavily damaged plants was found devoid of starch when tested with iodine solution.

The effects of the various concentrations used can be summarized as follows: 2 to 3% solutions proved fatal to all plants. 1.5% killed the majority and stunted the rest seriously; 1% killed one half and produced yellow leaves and root-rot in the rest. The 0.5% solution killed about one third of the seedlings while it provoked partial fading of the chlorophyll and did some damage to the roots in the surviving plants. Among the surviving plants we found cases where the distal portion of the main root had died while its proximal portion had formed callus and young lateral roots above it.

In the group damaged by 2,4-D dissolved in percolating irrigation water leaf curling was observed on the immature growth only, while extensive damage to the roots resulted in the death of the cambial tissue recognised by easy peeling away of the cortex at the damaged places. — All untreated seedlings remained healthy. No difference worth mentioning in the reaction of sweet lime and sour orange was observed.

DISCUSSION.

HAMNER, MOULTON and TUKEY (1) stated that pea-seeds failed to sprout and beans germinated in an abnormal manner producing stunted seedlings when they were sown one week after spraying the soil with 2,4-D one part per 10,000 parts of dry soil. Those authors also stated that the seeds of certain wild species are more resistant, but even in these cases seedlings are stunted and finally killed. Accordingly, the authors succeeded in their experiments of disinfection of organic manure and uncultivated soil infected with seeds of noxious weeds by spraying with 2,4-D. MARTIN (2) in accordance with our own results, found leaf curling, wilting and subsequent death in citrus seedlings within four to five weeks after application of 0.001 to 0.01% solutions (in terms of dry soil weight) of 2,4-D. YOUNG (5) describes damage inflicted upon various citrus trees and herbs by spraying with 2,4-D on both soil and leaves. The noxious influence increased in proportion to quantity and concentration of the poison and the surface of the leaves. This investigator also became convinced that the substance is absorbed by the roots. He warns against use of 2,4-D in concentrations exceeding 0.05% in citrus groves. ROBBINS (3) described characteristic damage in cotton and grape vines by irrigation water polluted by this substance after use for weed control in irrigation ditches. TUKEY, HAMNER and IMHOFE (4) describe histological changes which take place in *Convolvulus arvensis* L. and *Sonchus ar-*

vensis L. consequent upon spraying with a 0.1% solution of 2,4-D. They noted cessation of chlorophyll production and its absence from the majority of the leaf cells. Starch disappeared from all parts of the flowers and from the inner layers of the cortex of stems and roots. Flowers failed to develop normally, while vigorous cell divisions took place in the veins of the leaves, in the cambium and phloem region and in the vascular strands of stems, rhizomes and roots. — Our own findings evidently resemble in many respects those of the mentioned authors. They corroborate the findings of YOUNG and show that 2,4-D is hardly suitable for the destruction of the above-mentioned perennial grasses in citrus groves.

SUMMARY AND CONCLUSIONS.

Sprayings with 2,4-D in a concentration of 0.5% and more have proved very poisonous to young plants, while weaker solutions are not effective enough for the extermination of monocotyledoneous perennial weeds causing damage in citrus groves of Palestine. The poison is absorbed by the roots of citrus seedlings causing damage if applied to the soil near the root-crown or if brought in contact with the plants by streaming irrigation water.

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EXPERIMENTS WITH UNFRUITFUL VALENCIA ORANGE TREES *

By N. PLAUT

In 1943 Dr. H. R. Oppenheimer suggested to the author an investigation into the unfruitfulness of a few groups of Valencia trees causing losses to their growers in Palestine. His own researches on a similar subject are being published as a bulletin of the Agricultural Research Station, Rehovot (4).

Though the results obtained by the author are not encouraging, they seem to warrant publication as a modest contribution to the knowledge of factors determining fruit set in Citrus trees, a problem which is being studied in various countries such as California, Florida, and North-Africa.

Some cases of continuous very low yields in Valencia trees had been reported to the Research Station from groves in the coastal belt. The trees were of normal size, but bore not more than 25 to 140 fruits, compared with a normal average of about 500—1000 fruits for such trees in Palestine. In all cases the trees had always been amply supplied with water and nutrients, and the budwood had been taken from normally fruitful trees. Blossoming was normal in quantity in all cases.

In theory, such unexpected low fruitfulness may be a consequence of a mutation in the budwood. Mutations are relatively common in *Citrus*. In our case, such a genetical change may have affected the ability for self-fertilization or for parthenocarpy.

I. POLLINATION

The problems connected with fruit production in *Citrus* are different from those in deciduous fruit trees of the *Rosaceae*. The tendency towards parthenocarpy which is often pronounced in high-bred Citrus varieties, overshadows the problems of fertilization, so important in apples, plums etc. where the usual horticultural remedy for self-incompatibility is the interplanting of different varieties to bring about cross-pollination.

Nevertheless, there are some few cases in *Citrus*, where cross-pollination resulted in better yields than self-pollination. (2, 3, 4, 7). In these few cases it seems that the tendency towards parthenocarpy is relatively weak, and yields depend therefore on compatibility, while in many other cases, where the tendency towards parthenocarpy is strong, self-incompatibility does not become manifest in reduced yields, but can be detected by comparison of the number of seeds after self- and cross-pollination.

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* Abridged translation of a thesis presented to the Hebrew University in 1944 for the obtainment of the degree Master of Agricultural Science.

EXPERIMENTS

The effects of self-pollination, cross-pollination and lack of pollination on fruit yield and quantity of seed were tested on the unfruitful trees referred to above. In addition, the styles of yet unpollinated flowers were broken off, a practice recommended by SOKOLSKAYA (8).

The cross-pollinators chosen where : the grapefruit Duncan, the pollen of which is known to be very viable; the mandarin Dancy which had given good results with Clementine in OPPENHEIMER's experiments (4) and which is commercially desirable; and the sour orange. The percentage of pollen germination of the varieties involved was examined in a 15% saccharose solution. The average data found were (extremes in brackets) : for Dancy 29% (0—93), for Duncan 23% (8—38), for sour orange 8% (4—15), for normally fruitful Valencia 7% (4—14), for unfruitful Valencia at Mishmar Hasharon 13% (4—19), and for unfruitful Valencia at Ramat Hakovesh 8% (4—19).

Even if we assume that vital pollen is essential for fruit set, the germination results are not bad enough to justify the assumption that lack of viability of the pollen could be the cause of the low yields in our case (4,5).

100 flowers each were pollinated with pollen of the 3 abovementioned Citrus varieties, and with their own pollen. As an additional check, 100 flowers were left for free pollination. In 50 flowers the style was covered with tin-foil caps before the petals had unfolded, to prevent pollination. Each of these treatments was carried out in 2 groves, at Mishmar Hasharon (M. H.) and Ramat Hakovesh (R. H.). In addition, the styles of 100 flowers were broken at R. H. before pollination had taken place.

Results : At M. H. 1 fruit matured after pollination with Dancy pollen, 2 with Duncan pollen, 1 with sour orange pollen, 5 with own pollen, 7 after free pollination, while no fruit set where pollination was prevented. At R. H. the corresponding numbers for Dancy were 2, for Duncan 11, for Sour Orange 10, for own pollen 6, for free pollination 10, and for prevention of pollination 0. Six fruits matured from 100 flowers the style of which had been broken. The average number of seeds per fruit in both groves was : 3,0 for Dancy, 6,3 for Duncan, 5,6 for Sour Orange, 2,7 for selfpollination, 2,8 for free pollination, 0,7 for breaking of styles.

After crosspollination with Dancy the fruit set was very low, possibly because the style of the Dancy flower is shorter than that of Valencia, and the Dancy pollen tube may find difficulty in reaching the ovules of Valencia. The low number of seeds seems to corroborate this explanation especially as Dancy pollen proved to be highly viable (4), when Clementine flowers were pollinated.

The results with Duncan and Sour Orange pollen differed greatly in the 2 groves. If the results from both groves are averaged,

though this may be open to some objection, an average fruit set of 6,5 for Duncan and of 5,5 for Sour Orange is obtained, which is almost identical with the results of self-pollination. The seed counts seem to indicate a better compatibility between the pollen of either cross-pollinator and the Valencia pistil than between the Valencia pollen and its own pistil. Yet this moderate self-incompatibility cannot explain the low yields of the trees in question.

When the style, left intact, was bagged before pollen could reach it, no fruit set; thus autonomous parthenocarpy did not occur. But it is very interesting that, when the unpollinated style was broken, fruit set was normal, parthenocarpy apparently being induced by the wound stimulus. While the fruits from self-and cross-pollinations did not show any morphological peculiarity, those produced after the styles were broken, were among the largest of the trees. 5 out of 6 were absolutely seedless while the sixth contained 4 seeds. This may be a case of pollen germinating on the wound, or of autonomous apogamy, which according to some investigators may occur in *Citrus*.

It may be concluded from these experiments that partial self-incompatibility is not the cause of the low yields in the cases considered, as the more compatible pollen of Duncan and Sour orange did not raise the fruit set.

II. APPLICATION OF GROWTH SUBSTANCES

In an additional set of experiments we attempted to improve the fruit set of unfruitful Valencia trees at Qvutsat Schiller by treatments with synthetical growth substances. The theories of Gustafson (1) elucidate some problems of sexual reproduction in plants, as governed by phytohormones. Here, as in vegetative growth, phytohormones provide the stimulus. The pollen tube carries them to the ovule and thus initiates seed and fruit growth. This explains why in some cases unpollinated pistils start growing when supplied with growth substances in some other way. Gustafson demonstrated that unfertilized pistils of plants inclined to parthenocarpy contain a greater concentration of phytohormones than those of plants bearing fruit only after fertilization. In normal fruits the growing seed produces phytohormones and thus growth of the fruit is stimulated continuously. While treatments with growth substances were successful with many plants, and yields of parthenocarpic fruit were obtained in *Cucurbitaceae*, tomato, cherry, raspberry, *Gladiolus,* egg plant and others, little success has so far been attained in *Citrus* plants.

As mentioned before, a possible explanation of unexpected cases of low fruitfulness in *Citrus* may be furnished by a mutation which reduces the ability of the plant to produce parthenocarpic fruit. A remedy for such cases might be the artificial application of growth substances.

EXPERIMENTS

In our experiments, growth substances were used as free acids, 0,1% of aerosol being added as emulgator. The emulsions used were: α-naphthalene-acetic-acid (concentration 1/10,000), naphthoxy-acetic-acid (1/1000), 2,4-dichlorophenoxy-acetic-acid (conc. 1/10,000), (henceforward abridged NAA, NOA and 2,4-D respectively), and a mixture of equal parts of 2,4-D (conc. 1/10,000) + NOA (conc. 1/1000).

The first series of sprays was carried out on the 26th April 1944. The diameter of the young fruit was then 2—4 mm. Almost no petals were left on the trees, but most styles were still attached to the ovaries. The final count gave the following results (percentage of fruits which matured out of 300 young fruits treated with each emulsion): NAA — 2,7%; NOA — 1,0%; 2,4-D — 2,7%; NOA + 2,4-D — 2,3%; check treatment with 0,1% aerosol — 4,0%; and check without treatment — 3,8%.

The second series of sprays was carried out on the 7th June 1944 after the main drop, when the diameter of the fruits was 7—8 mm. The results were (percentage of fruits which matured out of 100 fruits treated in each case): NAA — 22%; NOA — 18%; 2,4-D — 25%; NOA + 2,4-D — 13%; check without treatment — 17%. Generally speaking, the results of the early treatments were negative, with a marked advantage for the checks over the growth substance treatments. The later series gave better results, the treatments with NAA and 2,4-D showing a marked advantage over the check. The combination of NOA and 2,4-D apparently had a negative effect.

An interesting incidental observation was made when on the 21st May 1944 it was found that the styles had not dropped off the fruits which had been treated with NOA and with 2,4-D, and no abscission layers had formed, while the untreated fruits and those treated with NAA had shed their styles. This is remarkable since just NAA is known for its property of preventing the formation of abscission layers in plants.

The limited scope of the experiments does not allow a statistical evaluation of the results. Yet it may be concluded that the growth substances used had no striking effect on the fruitfulness of the Valencia trees. This is in line with the results of other authors who tested the response of *Citrus* to growth substance treatment of the flower and fruit.

Summary: Attempts were made in 2 sets of experiments to increase the fruitfulness of unfruitful Valencia trees. Neither cross-pollinations with pollen of Dancy, Duncan and sour orange nor breaking of the styles increased the yield. Yet breaking of the styles rendered interesting results in respect of the quality of the fruit. Sprays with emulsions of α-naphthalene-acetic-acid, naphthoxy-acetic-acid and

2,4-dichloro-phenoxy-acetic-acid had no striking effect on the fruit yield.

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STUDIES ON THE WATER BALANCE OF UNIRRIGATED WOODY PLANTS

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FOREWORD

In 1932 the present author published an account of studies undertaken at Jerusalem and meant to afford a first insight into the water economy of natural Mediterranean vegetation under the extreme conditions prevailing in Palestine (10). We could since do relatively little to continue these studies while EVENARI and his associates undertook similar research. Of this work a recent contribution by POLJAKOFF (15) deserves to be mentioned here as a direct continuation of our own studies at Jerusalem, with the almond, carrob and olive trees.

Refraining from publication of scattered observations and measurements we publish here two small contributions to the problem: one on cases of extreme restriction of water expense, the other on the different water supplying power of various stocks used in commercial fruit plantations. Both studies concern conditions prevailing at the end of the dry season. A further contribution to the water economy of forest vegetation in the Carmel region will soon follow as part of a geobotanical investigation carried out in cooperation with H. BOYKO. This is to be published elsewhere, but some of its results are anticipated here.

I. SOME CASES OF EXTREME RESTRICTION OF WATER EXPENSE BY MEDITERRANEAN TREES AND SHRUBS

SCHIMPER'S (17) view that under identical conditions xerophytes always spend less water than mesophytes has been found a fallacy, but most modern authors will accept MAXIMOV'S (7) conclusion that this is true for conditions of water shortage.

Xeromorphic structures like thick external walls of the epidermal cells covered by cutin or wax can hardly be considered a useless luxury. Together with effective closure of the stomata and other internal structures or physico-chemical mechanisms, they act effectively indeed to balance the water economy of leaves, if dangerous conditions of edaphic and atmospheric drought threaten the existence of the plant.

Strangely enough, most authors studying plant transpiration under natural conditions have been intent on establishing figures of extremely high transpiration rates rather than on determining minimum figures. The latter are, however, of outstanding interest in connection with the above problem, viz. the elucida-

tion of the effectiveness of xeromorphic structures. HUBER (3), reporting on our earlier study, justly emphasized this point.

It should be recalled here that restriction of water expense of the leaves to values too small to be measured by HUBER'S transpiration balance has been shown in our previous study to occur in the Aleppo pine and in *Laurus nobilis*. Transpiration figures equalling or very closely approaching zero could also be established for *Ceratonia Siliqua, Arbutus Andrachne* and drought adapted bushes of *Rosmarinus officinalis*. The same was not found to apply to *Olea europaea* where we arrived at the conclusion (p. 208) that in extreme conditions transpiration intensity drops to a minimum figure of 15 milligrams per gram fresh weight per hour.

It seems interesting, therefore, now to report that we have since found in the olive, too, a decrease of transpiration intensity to a level too low to be measured by Huber's balance. This occurred during the last days of our activity as plant physiologist of the Hebrew University. On September 25th, 1933, a hot day, we tested at 12.48 an olive tree on very shallow, chalky soil which looked very dry. Injection tests with kerosene rendered negative results: the stomata were evidently closed completely. Correspondingly, one leaf each plucked at random from the sunny and the shady portion of this tree lost nothing of their weight during a few minutes' exposure on the balance, in spite of extreme atmospheric conditions.

In 1939, we reported a similar case in leaves of irrigated Jaffa orange trees investigated during a May khamseen at Rehovot. No other case of such extreme restriction to a value not measurable by transpiration balance was found during this investigation which covered the period of one year (11).

Investigating the daily course of transpiration in the natural maquis vegetation at Mt. Heitary (Carmel region) during the summer of 1946, we have found several further cases of apparent stoppage of transpiration during the hot hours of bright summer days. These were observed in leaves of *Quercus calliprinos* and *Laurus nobilis*. While our records do not indicate such cases in March and April, they were rather frequent on June 28th, when six single leaves of *Quercus* and three of *Laurus*, tested at various hours before and after noon, did not lose even half a milligram of their weight during two minutes' exposure. On September 29th, the same was observed in two cases on *Quercus* and in five on *Laurus*. On June, 26th, we even made, in the afternoon, one such observation on *Pistacia palaestina*, but this remained quite isolated. Apparent cessation of transpiration during day-time was thus found to be a phenomenon occurring almost exclusively in sclerophyllous leaves under conditions of severe lack of water in the soil. It was never observed in *Phillyrea media*, which always kept its stomata open, in contrast to *Quercus calliprinos* and *Laurus*, the stomata of which were found nearly or even completely closed throughout the day during the late summer months.

Encouraged by the above results, we tried to find further cases of apparent total suspension of water expense at Rehovot, on October 4th, 1946. Unirrigated specimens of *Myrtus communis, Citrus Limetta var. dulcis, Pinus halepensis, Olea europaea* and *Cupressus sempervirens* were investigated. Of these, *Pinus, Olea* and *Citrus* looked as if they suffered from very serious water shortage, as no rains had fallen for about five months. Temperatures during the weighings were about 27°C.

The leaves of the (unbudded) sweet lime trees were found to be still losing weight by water expense. Even when at the extreme limit of desiccation, they lost between 26 and 47 mg/gh of their fresh weight. Injection tests with kerosene showed that stomata were still at least partially open. With a myrtle, a transpiration rate of 87 mg/gh was still established at 11.41 a. m. However, four pairs of delicate pine needles of the previous year's growth, tested at 11.27 a. m., failed to lose measurably in weight during two minutes' exposure, while younger needles still lost 28.7 mg/gh at 8.32 a. m. A small leaf of the olive weighing 70 milligrams was found not to lose in weight during two minutes' exposure at 1.00 p. m. The same can be stated for a lateral branchlet of *Cupressus sempervirens var. horizontalis* weighing 206 mgs. which was tested at 1.09 p. m. This branchlet, left on a table in the open in half-shade, lost during the subsequent three hours only 7.5 mgs which corresponds to a transpiration intensity of 12 mg/gh.

The investigation of that day thus confirmed the ability of needles of the Aleppo pine and of leaves of the olive to restrict their transpiration to values approximating zero and added another conifer, *Cupressus*, to the list of plants able to effect such a surprising degree of water economy by both stomatal and cuticular restriction.

We may add that Poljakoff (15), after smearing the lower side of leaves of *Olea* and *Ceratonia* with vaseline in August and December, 1939, was unable to find any cuticular transpiration losses during exposure for three to ten minutes. These results agree with ours, indicating the large extent to which sclerophyllous leaves are capable of preventing loss of water through the walls of the epidermis after stomatal transpiration has been excluded.

In conclusion, we wish to remark that we are aware of the possibility that in the cases described here some water loss too small to be measured by our method might have taken place. However, we feel sure that it did not exceed 5% of the fresh weight per hour and is, therefore, of little ecological importance. In all the cases mentioned, no covering of the wounds caused by the severance of leaves or branchlets from the mother plant took place. It is all the more remarkable that transpiration was actually reduced to values too low to be measured in weighing individual leaves on a transpiration balance delicate enough to permit readings of half a milligram.

II. THE WATER BALANCE OF UNIRRIGATED APPLES AND PLUMS IN THE JUDAEAN HILLS IN LATE SUMMER

A. *Introduction*

The success of fruit growing in the hill country of Palestine, where water is scarce, depends primarily upon the adjustment of the cultivated varieties to drought resistant stocks which supply the scion with sufficient water during the blossoming period (when hot spells are frequent) and throughout the hot summer months, when the fruit is growing and ripening.

Although stock experiments with apples, plums, peaches, apricots, etc. have been carried out by the Jewish National Fund, the Agricultural Research Station and Government authorities for more than 20 years, these studies have, so far, not been supplemented by physiological tests of the water supplying power of the main stocks. Such tests appear, however, highly important for the correct interpretation of the results of stock trials as it is generally recognised that, besides temperature, soil drought is the principal factor determining success and failure of fruit growing in this country. Consequently, if a stock proves unsatisfactory, it will be justified in many cases to presume that the trouble is connected with an insufficient water supply from the rootstock, which in turn leads to abnormally high water deficits in the organs of the scion.

In 1940 the present author hoped to undertake extensive investigations into the water relations of budded fruit trees. World War II indefinitely delayed the execution of these studies which had been planned with the help of a grant from the Colonial Development Fund. Only a preliminary study could be made in September 1940, to gain some insight into (a) the turn-over of water in the leaves of the scion, (b) the restriction of water expense by stomatal regulation, (c) the level of saturation deficits in the leaves etc., i. e. on problems which could be studied with little or no assistance, in a few days of experimental work.

Though the data obtained are scarce, the results seem interesting enough to justify their publication, as practically nothing is as yet known about the subject as far as Palestine is concerned.

B. *Methods*

1. Intensity of transpiration was measured by rapid weighings with Huber's (2) transpiration balance which was also used in earlier studies. Only leaves well exposed to light were chosen.

For recent criticism of this method compare the contributions of Konis (5) and Mendel (8). No method of greater reliability is so far available for plants naturally rooted in the soil.

2. Maximum water saturation deficit of the leaves was determined by Stocker's (19) method.

3. Stomatal width in apple foliage has been determined, so far, by four methods. Pickett (13), working with Lloyd's alcohol fixation method, found closed stomata in orchard trees after 8 or 9 a. m. This behaviour stood in

marked contrast to the pronounced photosynthetic activity of the leaves, and PICKETT writes that "there is probably a certain amount of error" in the statement that "on some days" the stomata were closed during the entire 24-hour period. In fact, MAGNESS and FURR (6) had shown earlier that they "were unable to employ this method with apple foliage, as the stomata appeared to close in the rather thick epidermal strips when plunged into absolute alcohol".

The present author is able to state from experimental evidence that individual apple stomata found wide open in air in tangential sections (cut from the lower surface of the leaves with mesophyll tissue adhering to them) narrowed immediately by 30—50% upon addition of alcohol. Half open stomata closed entirely, or to narrow slits, under the same conditions. Where dioxan [NADEL (9)] was used instead of alcohol, even wide open stomata were found to close completely. These observations seem to explain sufficiently why PICKETT obtained erroneous results with LLOYD'S method.

MAGNESS and FURR (6) obtained good results with quick microscopic measurements of 50 stomata each in dry epidermal strips torn from the freshly plucked leaf. While they also tried MOLISCH'S injection method, their paper contains no indication regarding the liquids used therein nor do these authors adduce experimental evidence for their statement, that this method rendered "less accurate quantitative results" than the microscopical measurements on strips.

Our own studies confirmed that apple stomata can easily be tested under the microscope. They preserve their state of aperture for a prolonged time in rectangular pieces cut from the leaves and kept dry between slide and coverglass. But we have found that in thin sections taken from the lower side of the leaves, under the same experimental conditions, stomata, beginning in the marginal zone, sometimes close rather rapidly by hydroactive reaction [STALFELT (18)].

The application of MOLISCH'S injection method is somewhat difficult for the following reasons: (1) the hairs covering the lower side of the leaves render observation of the spots produced by the penetrating liquids rather cumbersome; (2) the infiltration of the epidermis takes place often at the margin of the drop, not at its centre; (3) with kerosene at least, there are no separate spots which coalesce later on, but big greasy spots appear fairly soon even when apertures are small.

In our own experiments, the injection method with suitable liquids (see below) has rendered satisfactory results.

In the case of p l u m s, it seems that LLOYD'S alcohol fixation method has given good results, when used by HENDRICKSON (1) to test French prunes in California.

While the stomatal width in leaves of Burbank's Japanese plum hybrids can also be tested, by direct microscopic examination, in punches or pieces cut from the leaves (which are observed in air), we found that the injection method renders useful results for a quick orientation, as required in ecological field work. It was decided, therefore, to adopt it in these studies. While kerosene penetrates into relatively narrow slits, a mixture of castor and turpentine oil in the proportion of 1:2 penetrates only at higher apertures, while paraffin oil

produces injection spots only if apertures are very wide. Expressing results of several consecutive injection tests made with several leaves in cumulative figures, a method first adopted by Pisek and Cartellieri (14) and developed later on by Oppenheimer and Elze (12) for use with citrus leaves, we obtained plausible results.

4. Osmotic value. The osmotic value of leaves of apple stocks was determined by De Vries' plasmolytical method in the epidermal cells of the leaves, using saccharose solutions differing from each other by 0.10 Mol. The application of this method was found difficult and required great care for two reasons: (1) the tissue soon becomes moribund; (2) it is by no means easy to make reliable statements about plasmolysis in the scattered surviving cells; here the process takes place with pronounced convex border-lines (while concave lines are frequent in damaged cells). The viscosity of the plasma seemed to be rather high at this season.

C. *Site and trees*

The collection of fruit trees and vine varieties of the Jewish National Fund at Qiryat Anavim settlement, in the Judaean hills, N. W. of Jerusalem was chosen for these tests. The trees were growing on the borders of a valley connecting the settlement with the main road from Jerusalem to Jaffa. The tested plum trees of the Santa Rosa variety were budded on almond and Myrobalan stocks while apples were budded on doucin, European seedling and on Hashabi, a local apple variety extensively used in Palestine as a stock. The plum trees were about 13 years old, growing near the watchman's house, at the edge of the pine forest. The specimens on almond stock were much stronger than those on Myrobalan. On both stocks shedding of the leaves had set in. While this shedding was moderate on almond stock, the trees on Myrobalan had lost a considerable proportion of their leaves.

Apple trees tested were rather young, about 4 to 6 years after budding. All the trees were grown on terraces where the depth of the soil was about 40 to 80 cms. overlying calcareous rock. Water-supply in late summer thus depended largely on the capacity of the roots to exploit water resources in the fissures of the bed-rock.

D. *Experimental Results*

I. *Plums.*

Santa Rosa on almond and Myrobalan stock was tested on September 15th, 1940, in the early afternoon, between 14 and 16 p. m. At 14 p. m. air temperature was 29°C., relative humidity 67%; at 15 p. m. air temperature was 28.7°C., relative humidity 62%. The sky was cloudless, the sun uncovered.

Table I shows the results of the transpiration weighings.

TABLE I.

Transpiration of 6 leaves of Santa Rosa plum on a typical autumn day, at Qiryat Anavim

(milligrams per gram fresh weight per hour)

On Almond Stock			*On Myrobalan Stock*		
Time	*Transpiration*	*Average*	*Time*	*Transpiration*	*Average*
13^{59} p.m.	614		14^{12}	457	
14^{34} p.m.	379		14^{21}	762	
14^{38} p.m.	212	474	14^{25}	598	
15^{24} p.m.	359		14^{29}	685	660
15^{32} p.m.	322		15^{21}	591	
15^{37} p.m.	956		15^{41}	647	
			15^{45}	882	

We learn from these few tests that the transpiration of plum leaves assumes very considerable values as much as five months after the last rains. This is particularly true for the tree budded on *Prunus cerasifera* (Myrobalan) stock, where fluctuations about the average are rather small, while on almond stock, we find indication of a defective water balance: 4 of the 6 leaves tested yielded greatly depressed figures of water expense.

This is also suggested by the tests of stomatal aperture carried out twice during the above weighings, at 14^{15} and 15^{15} p. m. approximately. Though individual leaves gave widely divergent results, the figures for Myrobalan stock gave a decidedly higher average. Expressed in figures, the apertures indicated by the kerosene tests were: at 14^{15} p. m. — 27.5 on Myrobalan, 22 on almond; and at 15^{15} p. m. — 38 on Myrobalan as against 22 on almond.

An almond leaf from a root sucker of the Santa Rosa tree with wide open stomata was tested at 16^{17} p. m. for comparison. It yielded the enormous transpiration figure of 1237 mg/gh.

At 17^{00} p. m. leaves of the tree budded on almond were tested for starch by Sachs' iodine test. They were found to contain no starch.

All these data seem to suggest that the Santa Rosa scion on almond stock suffered from defective water supply which also seemed to exert an adverse effect on its photosynthetic activity (by restricting stomatal aperture). This finding is not surprising, as Santa Rosa budded on almond is known to suffer from defective bud-union.

Though our few experiments are not wholly conclusive in their results, and the stronger shedding of leaves might possibly be responsible for the relatively better water balance of the leaves remaining on the tree budded on Myrobalan, the results seem, nevertheless, encouraging and further studies worth while.

2. Apples.

The next day, September 16th, was devoted to the study of a single apple tree, about 1.70 metres high, of the Grand Alexander variety. It was budded on unknown stock, probably Hashabi. Transpiration figures were generally much lower than those found before with plums. Details of this experiment are presented in table II.

TABLE II

Transpiration of leaves of a Grand Alexander apple tree at Qiryat Anavim, September 16th, 1940

	$9^{00}-10^{00}$ a.m.	$10^{00}-11^{00}$ a.m.	$13^{00}-14^{00}$ p.m.	$14^{00}-15^{00}$ p.m.	$15^{00}-16^{00}$ p.m.
Air temperature (°C)	24.7	25.0	29.5	28.0	27.0
Humidity (%)	77	70	57	55	61
Evaporation (Piche) (ml)	0.3	0.5	0.56	0.3	
Cloudiness*)	3	(?)	1	1	0
Wind (Beaufort)	not recorded	not recorded	not recorded	W3	W3—4
Transpiration	240	370	155	264	246
at consecutive	313	331	270	250	159
weighings of different	215	363	329	282	268
leaves (mg/g.h)		311	259	225	323
		226	250	374	
Hourly average	256	310	246	296	249
Stomatal aperture (closed = 0, maximum = 80)					
Kerosene	0	42.5	20	28	42
Castor + turpentine oil		7.5	4	7	18
Microscopical observation	closed	small percentage slightly opened			

Note: Figures for air temperature, humidity and cloudiness were established at the beginning of the one hour periods indicated in the table.

We learn from the table that transpiration figures on this typical summer day fluctuated in most cases between 250 and 350 mg/g.h. Even in the hottest hours of the day no higher values were attained. This suggests restrictions in the water supply to the leaves, since a relatively tender leaf, such as that of the apple, would otherwise be expected to undergo higher transpiration losses at least at the high temperatures and low humidities which prevailed bewteen 13

*) In the early morning weather was very cloudy after dew had fallen at night.

and 15 p. m. The fact that the stomata were closed or only slightly open throughout the day, seems to support this interpretation.

Between 13 and 14 p. m. 3 leaves each were plucked from four trees belonging to four different varieties, and their water saturation deficits were determined. The following results were obtained:

(1) Grand Alexander on Hashabi stock: 10.6; 13.2; 11.1%.

(2) Winter Banana on Hashabi stock: 15.0; 5.1; 9.7%.

(3) Delicious on unknown stock: from lower branch 11.5%; from medium branch 9.8%; from top 20.5%.

(4) Ontario on unknown stock: from lower branch 6.6%; from medium branch 7.2%; from top 12.4%.

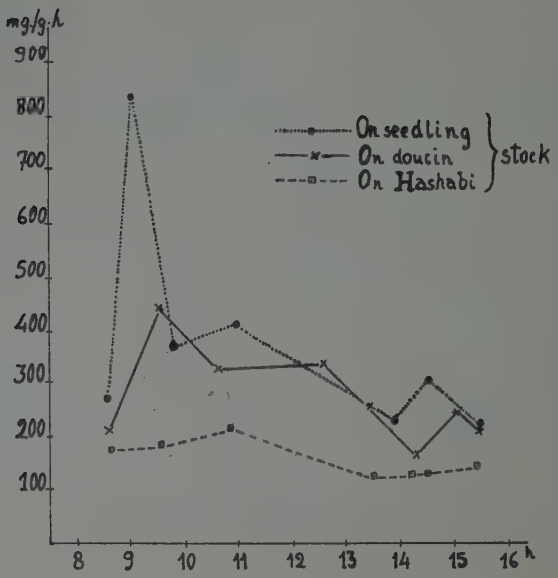
While the general level of these deficits does not appear unduly high, deficits above 10% must nevertheless be regarded as considerable. They suggest that the trees were unable to balance their water budget in spite of drastic restrictions of their expenses. This, however, can so far be stated only to apply to the hottest period of the day.

It is interesting to note that in the Delicious and Ontario varieties, as far as can be gathered from our data, leaves from the top showed higher deficits than leaves plucked from a lower level.

The next day, September 17th, was devoted to a study of transpiration of one apple variety, Winter Banana, budded on three different rootstocks: seedling, doucin and Hashabi. These trees, grown as bushes, were planted under comparable conditions in blocks, each on a different stock, on a terrace along the road leading to the settlement. They were very well developed, had reached heights of 2 to 3 metres, and were fairly uniform in size, in spite of the different rootstocks.

The weather was hot and dry, with a maximum temperature of 34°C in the shade at 13 p. m. when relative humidity fell to 35%. There was no wind or only slight air currents from the South (at 15^{00} p. m., a NW drift was noted, which is common in Palestine under summer conditions). While the sky was clear in the morning haze and cirrhi began to appear from 13 p. m. onwards, but the sun was uncovered throughout.

With only one balance at our disposal, no more than 6 to 9 leaves per hour could be weighed, i. e. 2 to 3 from each block. No stomatal tests or observations could be carried out, and only the usual meteorological readings could be taken in addition to the weighing. The Piche evaporimeter was suspended in the top of a tree, as on the preceding days. Weighings lasted from 8 a. m. to 16 p. m. being discontinued between 10^{50} a. m. and 12^{30} p. m. Thus a somewhat incomplete, but highly interesting picture of daily transpiration was obtained which is represented in figure 1.



The figure shows that transpiration on seedling stock reached a high peak at 9 a. m., when weighings yielded the maximum figures of the day: 864 and 806 mgs/g.h., respectively. This was followed by a steep fall to a level of about 350 mgs/g.h (10 a. m.). Afternoon figures were still lower, in accordance with conditions of soil and atmospheric drought; they fluctuated between 200 and 300 mgs/g.h.

On doucin stock, transpiration was somewhat lower. At its highest, between 9 and 10 a.m. the maximum transpiration reached 675 mg/g.h. The further course of the curve was similar to that for the seedling stock. But in the afternoon, when transpiration was at its lowest, we established on doucin 3 figures below 200 mg/g.h. while this did not occur on trees on the former stock.

Transpiration on Hashabi was greatly depressed throughout the day, fluctuating between 100 and 200 mg/g.h., with two unimportant exceptions. This fact undoubtedly shows that the trees budded on this stock suffered from a definite and serious shortage of water supply. Owing to prolonged drought effects the stomata were probably almost closed even in the morning hours and this prevented the transpiration curve from rising between 9 and 9^{30} a. m. in the manner observed on both seedling and doucin stock.

The result of this day's investigation thus showed that Hashabi did not supply sufficient water to cover the needs of the scion budded

onto it. This seemed to be further confirmed by determinations of the water saturation deficits, made on 3 leaves from each stock-scion combination and taken at 13 p. m. from the trees used for the transpiration experiments. While 2 leaves out of 9 did not absorb water and must be disregarded, the rest rendered the following results:

On seedling: 11.6; 10.6; 11.2%. On doucin: 11.0; 11.8%. On Hashabi: 21.3; 18.4%.

If these figures are typical, they could explain why the leaves on Hashabi stock (which were certainly not far from a state of wilting) were obliged to restrict their water expense throughout the day.

During the following days plasmolytical determinations of the osmotic value of the leaf epidermis were carried out on the three apple stocks. The leaves were taken from root-suckers. We thus hoped to establish whether or not differences in water supply are correlated with differences in the suction power of the rootstock. The determination of the exact concentration causing limiting plasmolysis was found difficult, since the tested cells did not behave alike in identical solutions, some showing plasmolysis, others not. The latter were possibly damaged or there may have been an abnormally high degree of viscosity of the protoplasm in these cells, so that plasmolysis was indefinitely delayed by weakly hypertonic solutions. The experiments, which were continued for one (or even two) hours, lead us to the conclusion that 0.8 Mol. saccharose solution caused a state much resembling limiting plasmolysis with both doucin and Hashabi while the figure for seedling stock seemed to be slightly higher than 0.8 Mol, but lower than 0.9 Mol. This means that the osmotic value of the epidermal cells was about 20—22 atmospheres.

The result shows, that the question raised above must probably be answered in the negative: The differences in the water supplying power of the various rootstocks, which are evident in the different physiological behaviour of the scion (water expense and saturation degree), do not appear to be due to different suction potentials of the stocks tested. We suppose that differences in the capacity of their roots to penetrate into the fissures of the rock underlying the soil may be responsible for the differential water supplying powers of these stocks.

It is a well established fact that the root system of the local Hashabi stock is usually very shallow, and for this reason apple trees budded on this stock are sometimes blown over by storms. Although we have not investigated the depth of root penetration at Qiryat Anavim, it is obvious that this stock should not be planted on too shallow ground, which is apt to dry out during summer.

Moreover, it should be pointed out in this connection that the vessels of the Hashabi are narrower than those of the seedling stock,

as shown by KOMAROFSKI (4) for Hashabi budded with Calville and Delicious.

Discussion

While the preliminary character of this study precludes practical conclusions it seems permissible to compare some of the results with facts known from similar work in Palestine and abroad.

The above figures of transpiration intensity and saturation deficit may first be compared with the results we have previously obtained with deciduous fruit trees at Jerusalem (10). We then found fig leaves to reach a maximum transpiration of 390.2 mg/g.h, which is by far surpassed by the figures for apple leaves on crab and doucin; almonds were in 1931 found to attain a maximum figure of 952.4 mg/g.h. (on Sept. 16th 1931 between 9 and 10 in the morning, under khamseen conditions), which is reached by plum, but not by apple leaves as studied under very similar conditions in 1940. Transpiration of plum leaves from unirrigated trees on Myrobalan stock was surprisingly high being comparable to mid-summer figures recorded with well irrigated citrus trees (8,11). For the latter the highest figure found so far is 1773 mg/g.h. (8).

As regards water saturation deficits of leaves, previous studies (10) at Jerusalem in late summer (September—October) have yielded figures of 9.9% for almonds and of 16.5% for figs, as compared with our present figures of about 10—12% for apples on seedling and doucin and about 18—21% on Hashabi stock.

The daily transpiration curves established for apple trees on September 17th should be compared with similar findings of ROUSCHAL (16) who investigated Mediterranean maqui-shrubs in Italy, during the summer. In the vast majority of cases he found a very early, steep rise of transpiration leading to a maximum as early as 8 or 9 a. m. often followed by an equally steep fall. Thereafter transpiration remained at rather a low level throughout the day. A daily course of transpiration such as that described here for apple on seedling stock is to be considered characteristic of soil water conditions still relatively favourable; reduction of this transpiration peak in the morning to a lower level, as found for apple on doucin, is justly interpreted by ROUSCHAL as a consequence of pronounced drought of the soil. We may add that such reduction may, of course, also be due to a relatively less powerful root system. Finally, apple on Hashabi stock presents the picture of a smooth curve never rising above very low levels. There is little doubt that these three types of transpiration curves are all produced by stomatal regulations. As long it is capable of doing so, the plant opens its stomata for the vital gas exchanges at least for some time in the morning. But with increasing tension of its water balance the plant is obliged to keep the stomata closed, or nearly so, even in the morning when the water deficit is at its lowest.

Finally we wish to stress the striking resemblance between the daily march of stomatal aperture of apples, as studied by MAGNESS and FURR (6) at Hancock (Maryland) on August 29th, 1930, with that of leaf transpiration of this species on September 17th, 1940 as described in this study. External

conditions were similar, though on the day of the experiment at Hancock morning temperatures were much lower, maximum temperature was 2°C lower, and humidity was about 7% higher, than at Qiryat Anavim. Common features of the curve established by MAGNESS and FURR for irrigated trees and of our curve for the transpiration of Winter Banana on seedling stock are: a peak at 9 a. m. (with more than 90% of the stomata open at Hancock), the subsequent gradual decrease to a minimum reached at 1.30 p. m. and the second peak, much lower than the first, in the afternoon. On the other hand, the American authors' curve for the unirrigated plot is intermediate between those we established for transpiration of Winter Banana on doucin and on Hashabi stock, respectively.

This comparison seems to show that organs of the same structure, such as leaves of the same species grown under comparable conditions, may be expected to behave similarly under like atmospheric and soil water conditions in the western as in the eastern hemisphere, in temperate as in subtropical climates.

From a horticultural point of view, it is interesting to note that a powerful stock such as the seedling is ,as it were, capable of creating for the scion "irrigated" conditions even in a semi-arid region.

In fact we have shown that the scion might still have a considerable turnover of water comparable to that of irrigated trees even after five long months of drought, though such turnover might last for fewer hours per day than with trees under irrigation. On the other hand, comparison of the curves recorded by MAGNESS and FURR (6) and in our own studies, underlines the fact that drying soil and unfit stock call forth similar reactions in the scion, restricting transpiration and probably also carbon dioxide assimilation.

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SUMMARY

The first part of the paper deals with cases of extreme restriction of plant transpiration after prolonged summer drought. Restriction to figures near zero have been reported in previous studies for *Pinus halepensis, Laurus nobilis, Ceratonia Siliqua, Arbutus Andrachne, Rosmarinus officinalis* and *Citrus sinensis*. The present report adds further cases established with plants of *Quercus palaestina, Pistacia palaestina, Olea europaea* and *Cupressus sempervirens*. The results show that certain sclerophyllous leaves represent highly effective structures for the prevention of both stomatal and cuticular water losses.

The second part reports on a preliminary study of water expense and water balance of unirrigated plum and apple trees, carried out in September, about five months after the last effective rains. Remarkably high figures for the transpiration of plums, averaging 660 milligrams per gram fo fresh leaf weight, were found in the early afternoon for Santa Rosa on Myrobalan stock while on almond

stock the average was 30% lower. With apple leaves tested on two consecutive days, figures were found to range about 200—300 mg/g.h. Much higher values rising above 800 mg/g.h. were recorded only about 9^{00} a. m. on Seedling stock, while on doucin the corresponding figure was about 500 and on Hashabi only 200 mg/g.h. Tests of stomatal aperture showed that the stomata play an important part in maintaining the water balance of the fruit trees studied but high saturation deficits of apple leaves on Hashabi stock seem to indicate that this mechanism of regulation is inadequate to protect trees on stocks with shallow rooting habits. No considerable differences in osmotic values were found to exist between Seedling, doucin and Hashabi stocks. The penetration of the roots into deeper or shallower soil layers and fissures of the rock seems, therefore to be the main factor determining the water supply of the scion under dry soil and air conditions.

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THE WOOD ANATOMY OF CERTAIN APPLE STOCK AND SCION VARIETIES AND CORRELATIVE STRUCTURAL CHANGES IN THE TRUNK INDUCED BY BUDDING*)

By B. KOMAROFSKI

I. INTRODUCTION

It is well known that the vegetative development of apple trees is greatly influenced by the stock. The same variety if budded on the stock East Malling XVI will produce a vigorous tree while on E. M. IX it will remain dwarfed. We are also informed about the influence of the stock on the shape of the scion's top, while conversely the scion will either weaken or invigorate the root system of the stock, according to the specific intensity of its carbon assimilation and its growing habits. The development of the budded tree further depends on the degree of compatibility of the partners. Disharmonic combinations form, as a rule, defective bud unions with tumor-like outgrowths above or below the line separating scion and stock.

The disharmony of certain combinations has often been investigated under its morphological and physiological aspects. Some investigators devoted their attention also to the anatomical structure of the transitional zone. But little attention has been paid to specific anatomical differences between stock and scion as the possible cause of such disharmony. Still less is known about the important problem whether, as may be supposed, the scion changes the specific structure of the stock in the neighbourhood of the union and vice versa. The present study was therefore undertaken in order to find out whether or not such correlative changes take place. Special attention was devoted to the vessels, wood parenchyma and wood rays as well as to possible structural features which might prove helpful in the identification of rootstock as well as scion varieties.

II. REVIEW OF PREVIOUS STUDIES

The problem of correlative changes in anatomical characters, as defined above, has been investigated earlier by BEAKBANE and THOMPSON (1) studying one to two year old apple trees. While refraining from final conclusions these authors could establish at least some correlation between vegetative vigour and certain characteristics in the composition of the wood. This enabled them to divide the rootstocks into a vigorous and a dwarf group according to anatomical criteria. These were: a) the ratio of the total width of the bark to that of the xylem body; b) the relative proportion in the latter of parenchymatous tissue, vessels and fibres. Provided that the thus

*) Abridged translation of a thesis presented to the Hebrew University in 1944 for the degree of Master of Agricultural Science.

defined correlation between anatomical composition and vegetative vigour persists later on, these authors conclude that it would be possible to recognize and eliminate weak types at an early stage by anatomical investigation.

Beakbane and Thompson (1) explain the reduced size of the E. M. IX stock by the anatomical characters of its wood. The narrowness of the vessels is supposed to interfere with the translocation of water and mineral nutrients. They further show that the high ratio between bark and wood, as found in E. M. IX, is characteristic of all dwarf stocks. The high proportion of parenchymatic storage tissues would seem to permit a considerable accumulation of carbohydrates. This, in turn, would favour the formation of flower-buds instead of vegetative buds and explain the strong and early productivity of the apple varieties budded on this stock.

In the second part of the above paper Beakbane (2) quotes the work of American authors (Roberts, Swarbrick) who have found that the scion exerts a morphological and an anatomical influence on the stock. They grafted a certain scion variety on one year old stocks and found that the wood produced in the stocks during the subsequent year resembled in its pattern that of the scion. although marked differences had been shown to exist in the roots of ungrafted seedlings. Beakbane however failed to find such an influence in her studies as "there was no indication that the internal structure of rootstocks had been made more uniform by the influence of the scion".

III. EXPERIMENTAL PROCEDURE

Samples for investigation were taken on January 6th, 1944 from a plantation at Giv'at Hayim, in the coastal plain, between Haifa and Tel Aviv. Here various combinations of stocks and scions are tested. The samples represented blocks of wood and bark which were cut out above and below the union by aid of chisel and hammer. They were 1.5 cms. long, 1 cm. wide and deep. Care was taken to sample at smooth places.

The following combinations were investigated by this method: Calville de San Sauveur and Delicious as scions on the stocks: E. M. I, II, IX, and XVI, Seedling, and Hashabi, a local apple variety widely used as stock. Further scion varieties tested were Gravenstein, Winter Banana, Reine des Reinettes and Rome Beauty, all budded on E. M. II. stock. A second series of samples was taken on March, 26th.

The samples were transferred into 40% formalin according to the method of Weinstein (4). After three weeks the blocks were investigated and, if found insufficiently softened for sectioning, transferred for further two weeks into a 1:1 mixture of glycerol and 50% ethanol. 15 microns thick sections were cut by means of a wood sliding microtome in transversal, tangential and radial directions. Of several stains tested, Pianeze III b was finally adopted. This

stains lignified tissue green, cellulose walls pink to red, and suberin yellow. Particulars concerning the preparation and use of this stain have been published by VAUGHAN (3).

Finally, the sections were mounted in Canada balsam. Counts of vessels and wood parenchyma cells were carried out under the microscope and have here been indicated in numbers of each element per square millimetre. Only in rare cases was it found worth while to carry out separate counts in the spring and summer wood, their structure being as a rule quite similar. If such differences occur, they seem, however, to bear specific character.

The fact should be underlined that the proportion and distribution of parenchymatous cells is not as constant as that of vessels. They therefore appear less important than the latter as auxiliary taxonomic or as correlative characters.

In each sample 50 vessels were measured by a projection apparatus in the dark room. Since cross-sections of vessels are elliptical, both the long and the short axis was measured in each case. Variance in the "fields" was analysed in each separate sample and afterwards in all homologous samples.

IV. THE STEM ANATOMY OF THE APPLE TREE

In the following we describe briefly the general structure of the trunk of apple trees in order to facilitate the understanding of specific differences. In mature apple trees, the external layers of the bark are suberized. Cracks in the splitted bark penetrate sometimes to the xylem body. If stems are not too old the bulk of the metaxylem is composed of active sap wood and only a minor portion is dead, brownish heart wood. Though annual rings are fairly well-marked, cases of sudden transitions from spring to summer wood are rare. Vessels are scattered. Tracheids are of common occurrence only in the protoxylem. Libriform fibres have thicker walls than vessels. The wood rays are uniserial, biserial or pluriserial. In the season of storage, numerous starch grains are found in the wood parenchyma, pith and rays.

The anatomical properties of the wood of the various stock and scion varieties may be summarized as follows:

Stocks

1.—E.M.I. U n i s e r i a l rays copious, appearing oval or asymmetrical in tangential section.

2.—E.M.II. Considerable percentage of high p l u r i s e r i a l rays. Vessels straight.

3.—E.M.IX. (dwarf). Cortex thick, parenchyma highly developed: pluriserial, rather low rays and very copious wood parenchyma cells, vessels scarce, narrow (1).

4.—E.M.XVI. (vigorous), Net of wood fibres much developed, vessels numerous and wide; parenchymatous tissue scarce.

5.—Seedling. Vascularisation weak, but fibrous tissue copious. Vessels sometimes twisted.

6.—Hashabi. Sharp contrast between spring and summer wood; very numerous vessels in the former. Parenchymatous tissue well developed.

Scions

Note:— Though anatomical differences between the scions are considerable they vary under the influence of various factors and particularly under that of the stock. This fact prejudices against their taxonomical value. In the following list characters have been chosen which have been found relatively stable and independent from the influence of the stock.

1.— Calville de San Sauveur. — Pluriserial rays rather numerous, vascularisation moderate, network of fibres well developed, wood parenchyma cells not copious.

2.—Delicious. Pluriserial rays scarce or lacking, uniserial rays frequent, if the variety is budded on E.M. I, IX or XVI, but not always if budded on E.M. II or Seedling.

3.—Winter Banana. — Remarkable for its uniserial, sinuous rays.

4.—Reine des Reinettes. — Structure similar to 3.—.

5.—Rome Beauty. — Vessels less numerous and narrower than in the preceding varieties; system of fibres however much developed.

6.—Gravenstein. — Vessels very wide, but their number small.

V. INFLUENCE OF THE STOCK ON THE SCION AND VICE VERSA

Unfortunately no unbudded specimens of either stock or scion varieties could be examined. Therefore it was found impossible to establish beyond doubt the "normal" structure of either. Instead we endeavoured to find relatively stable anatomical characters occuring in several combinations. These were tentatively considered as typical, while rarer deviations from this type were regarded as likely to be induced by the partner.

The slides were first subjected to a general inspection which allowed certain correlative shifts in the distribution of the main histological elements to be established. In a second inspection the area occupied by certain cell types was measured and counts of their number were carried out in order to substantiate the first impressions by exact methods. Results of both inspections are described separately, in accordance with the different weight of evidence obtained.

A. *Results of the general inspection*

1. *Stock influence on scions*

The anatomical structure of the Calville de San Sauveur on E.M. II, Seedling and Hashabi was found to be fairly constant and

to correspond to the above description. By contrast, deviations from this type of xylem composition were observed on the stocks E.M. I, XVI and IX.

Under the influence of E.M. I the proportion of pluriserial rays decreases, falling below that of biserial rays. The fibrous tissue increases in proportion. Few vessels and only scattered, isolated wood parenchyma cells are encountered. If budded on E.M. XVI, the Calville evidences the following anatomical characteristics: wood fibres with strikingly w i d e l u m i n a; wood parenchyma cells in groups of 4 to 5. On E.M. IX we found thick cortex, increase of parenchymatous elements and reduced diameter of vessels.

The variety Delicious shows a different behaviour. Its anatomical structure appears relatively stable and corresponds to the above description when budded on E.M. I, II and IX, while characteristic deviations were observed on Hashabi, E.M. XVI and seedling.

On E.M. XVI, the transverse section shows a somewhat spongy structure due to increased vacuolisation of the wood fibres, in analogy to the influence of this stock on Calville. On seedling a similar spongy structure arises but here it is a result of increased vascularisation of the xylem. The number of scattered wood parenchyma cells increases, surpassing 300 per sq. millimetre.

2. *Scion influence on stocks*

Generally speaking the correlative influence of the scions on the structure of the stocks was found to be much less pronounced than that of the stocks on the scions, being negligible in most cases. But an important exception to this rule was found in E.M. II stock budded with Gravenstein. Under the influence of this scion a pronounced shift towards a xylem type with f e w, w i d e v e s s e l s which is so characteristic of Gravenstein could be established.

B. *Results of the detailed inspection*

1. *Relative area of wood rays in tangential sections*

Calville as well as Delicious were tested on all six stocks. The relative area of wood rays in Calville was found to fluctuate between 19.5% (on Seedling) and 29.3% (on E.M. II). In the stocks fluctuations were wider and the relative area often greater, being smallest in seedling (20.2%) and highest in E.M. IX (42.4%). While thus the smallest area in the scion (on Seedling) coincided with the smallest found in any stock, no clear tendency towards parallel variation was found in the remaining combinations. With Delicious there was even a tendency to inverse variation. The smallest relative area which occurred in E.M. XVI (15.2%) corresponded to the greatest of the series (33%) in the scion, while the greatest (in E.M. IX: 46%) corresponded to 14.7% only in the scion. The smaller fluctuations in Calville, as compared with Delicious, suggest a higher stability of wood structure in the former variety.

An analysis of E.M. II budded with six scion varieties failed to furnish proof of scion influence. The relative area of the wood rays fluctuated within quite narrow limits (25—30.3%) while in the scions fluctuations were much more marked (from 15.2% in Reine des Reinettes to 29.3% in Calville).

E.M. IX behaved in a manner similar to E.M. II, while results with other stocks suggest a higher variability in the relative proportion of the wood rays. This is borne out by the following percentages:

Budded with	Seedling	E.M. XVI	E.M. II	Hashabi	E.M. I	E.M. IX
Calville	20.2	28.0	28.1	31.7	33.5	42.4
Delicious	15.6	15.2	25.0	23.0	17.8	46.0

In interpreting the above results, it should be borne in mind that of all these stocks, only E.M. II was investigated under the symbiotic influence of more than the two scion varieties Calville and Delicious. Therefore no general conclusions should be drawn from the results.

2. Density of vessels

The vessels were investigated in transverse sections. Their density is indicated in the tables as number per sq. millimetre. Each number represents the average count of five optical fields.

Table I shows the influence of the six stocks on the vascularisation of the scion varieties Calville and Delicious.

TABLE I

Density of vessels (no. per mm²) in the varieties Calville de San Sauveur and Delicious, as affected by various stocks

	Calville		Delicious	
Stock	vessels in stock	vessels in scion	vessels in stock	vessels in scion
E.M. I	161.5	115	138	146
E.M. II	202	146	161.5	230
E.M. IX	138	231	154	130—200*)
E.M. XVI	169	154	146	138.4
Hashabi	92—215*)	169	154	123
Seedling	123	154	107	200

We learn from the table that the stocks do not seem to exert a definite effect on the vascularisation of the scions. On the other hand, the xylem of the stocks appears rather more adaptable changing its composition considerably according to the scion (except E.M. IX and possibly seedling).

*) The first figure refers to late wood, the second to early wood.

Table II presents corresponding information regarding the influence of various scions budded on one stock, E.M. II.

TABLE II

Influence of different scions on the density of vessels in the xylem of E.M. II stock

Scion variety	Number of vessels per mm² in the scion	in the stock
Delicious	230	161.5
Rome Beauty	200	174 (146—202)*)
Reine des Reinettes	161.5	177
Calville	146	202
Winter Banana	130	161.5
Gravenstein	100	92
Average	for the first five species: 175	
Standard deviation	for the first five species: 30	

A glance at table II shows that in the first five cases the density of vessels in the stock is relatively little influenced by the scion, and variations show no parallelism. On the other hand the Gravenstein variety which has few vessels per square millimetre has evidently produced a very obvious reduction in the number of vessels of the stock, and this we consider a pronounced case of correlative influence.

3. *Size of vessels*

Measurements of the size of vessels carried out on transverse sections of Calville and Delicious on the six stocks have been recorded in table III. The table shows that a certain degree of adaptation of the width of the vessels in stock and scion actually takes place. A stock with narrow vessels provokes in the scion a tendency for the narrowing of its vessels. In this way a normal water supply seems to be assured. Thus the dwarfing stock E.M. IX with its narrow vessels provoked in both scions a marked decrease of the width of their vessels as compared with the other combinations. On the other hand, E.M. XVI which confers a strong vegetative development to the scion provoked in Delicious a remarkable relative increase, and similar observations were made with regard to the effect of Seedling on Calville. However, in other cases such parallel variation was lacking. Here other correlative influences may have interfered.

Finally, the influence of various scions on the width of the vessels of the same stock (E.M. II) was investigated. The vessels of the stock were found relatively resistant to the influence of the scions. In fact, their cross-section fluctuated only by ±12% if they were budded with Delicious, Banana, Reine des Reinettes or Calville,

*) See footnote to table I.

all varieties with very similar average cross-sections in their own vessels. But the cross-section in the stock decreased by about 20% with Rome Beauty as compared with the main group, and it was found that this scion had vessels narrower by about 30% than the main group of scions. Gravenstein, with an average cross-section of vessels more than double as large as that of the others, also produced the largest vessels in the stock, though the increase here was by no means proportional.

TABLE III

Influence of six different stocks on the size of vessels (in μ) in the xylem of Calville and Delicious

Stock	Calville de San Sauveur				Delicious			
	stock		scion		stock		scion	
	long axis	short axis	long axis	short axis	long axis	short axis	long axis	short axis
E.M.I	47.5	32.4	56.7	37.8	59.4	32.4	55.3	39.0
E.M. II	37.8	31.0	54.0	40.5	35.1	31.0	51.3	37.8
E.M. IX	34.0	21.6	45.9	29.7	29.7	21.6	45.9	35.1
E.M. XVI	43.2	29.7	55.4	39.2	51.3	29.7	62.1	40.5
Hashabi	44.2	30.5	64.8	32.4	48.6	30.5	58.0	41.5
Seedling	47.2	32.4	67.5	35.1	57.5	32.4	51.3	38.7

4. *Number of wood parenchyma cells*

Counts in the xylem of Calville and Delicious budded on the six stocks failed to yield positive evidence of any influence of the stocks on the number of wood parenchyma cells. Variations were large and irregular. Thus, in seedling budded to Calville, wood parenchyma cells were scarce (below 100) in both components while in the combination of the same stock with Delicious numbers of 300 and more were attained. The high figures found for E.M. IX, viz. 300 and 323, respectively, deserve emphasis (cf. fig. 1).

DISCUSSION

The present investigation has shown that a mutual correlative interdependence between stock and scion really exists as far as certain anatomical characters are concerned. Since, however, the number of investigated specimens was rather small and neither scion varieties on their own roots nor unbudded stocks could be investigated, the present paper should merely be regarded as a first step towards more detailed investigations. In these the influence of external factors upon anatomical structure should also be taken into account.

It seems remarkable that the influence of the stock on the scion has been found stronger than that of the latter on the stock. This agrees with the results of other investigators studying the morphological and physiological aspects of the problem.

In the structure of the stocks we find a negative correlation between the relative proportion of wood rays and the vegetative vigour of the stock. In the dwarf stock E.M. IX, the proportion is 40%, in the semi-dwarfing stocks E.M. II and E.M. I it amounts to 25—35%, while in vigorous stocks, such as Seedling, it falls to 20% and below.

A negative correlation also obtains between the size of vessels and the proportion of wood rays [cf. WEINSTEIN (5)]. This was found true in the case of E.M. IX where the vessels, though numerous, are of small size and the relative proportion of the wood rays rises to 40%. The interpretation of these correlations represents a complex problem which we do not propose to tackle here.

It would be interesting to investigate further whether the anatomical characters studied by us only in the stem, near the bud union, can be traced to the more remote parts of the stem and to the branches, and whether they are preserved at least near the bud-union throughout the life-time of the combination. If the problem is studied under such wider aspects it might also render sufficient evidence for an analytical key of wood structure useful for horticultural as well as taxonomical purposes.

Summary and Conclusions

The anatomical structure of apple stocks and scions was studied in samples taken near their union. Combinations studied in detail were Calville de San Sauveur and Delicious on East Malling stocks I, II, IX, XVI, and on Seedling and Hashabi. The varieties Reine des Reinettes, Winter Banana, Rome Beauty and Gravenstein were further investigated in combination with E.M. II. Attention was paid to anatomical differences between these stock and scion varieties and to correlative changes produced by their influence upon each other. Such changes were found to be brought about more often in the scion than in the stock, the latter provoking quantitative structural changes in the xylem body of the scion which render it more similar to the structure of the stock itself.

Thus the dwarfing stock E.M. IX which has a high proportion of pluriserial wood rays and wood parenchyma cells (while libriform fibres are scarce and vessels narrow) exerts an influence of this kind on the scions budded to it. This influence is most pronounced in the width of the vessels.

Generally speaking the stock E.M. II is only little affected in its anatomical characters by the various scions budded on it, but Gravenstein which has few, wide vessels, produces a marked decrease in the vascularisation of this stock.

In the stocks, negative correlations were established between the relative proportion of wood rays on the one hand and the size of the vessels and vegetative vigour on the other hand.

Anatomical differences between scion varieties have so far been found too variable to allow their use for identification and scientific classification.

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EXPLANATION OF PLATE I.

1). — Transverse section through the wood of the E.M.IX stock budded to Delicious. Parenchyma highly developed: great density of pluriserial wood-rays and wood-parenchyma cells, vessels scarce with narrow lumina; fibrous tissue reduced.

2). — Longitudinal section through the wood of the E.M.IX stock. The same characteristics as in (1). The pluriserial wood-rays appear rather low and wide.

3). — Transverse section through the wood of Calville scion variety, budded on the E.M.IX stock. The stock imparted to the scion some of its own characteristics such as a relative accumulation of wood-rays and a reduction of the fibrous tissue.

4). — Tangential longitudinal section through the wood of Calville scion variety, budded on the E.M.IX stock. The wood rays are fairly similar in shape to those of the stock.

5). — Transverse section through the wood of Calville scion variety, budded on the E.M.II stock. The structure is typical of the variety.

6). — Tangential longitudinal section through the wood of Calville scion variety budded on the E.M.II stock. The structure is typical of the variety.

7). — Transverse section through the wood of Gravenstein scion variety, budded on the E.M.II stock. The structure is typical of the variety.

8). — Transverse section through the wood of the E.M.II stock, budded to the Gravenstein scion variety. One notices a marked decrease in the density of vessels as a result of the influence of the scion.

9). — Transverse section through the wood of the E.M.II stock, budded to Calville scion variety. The structure is typical of the stock.

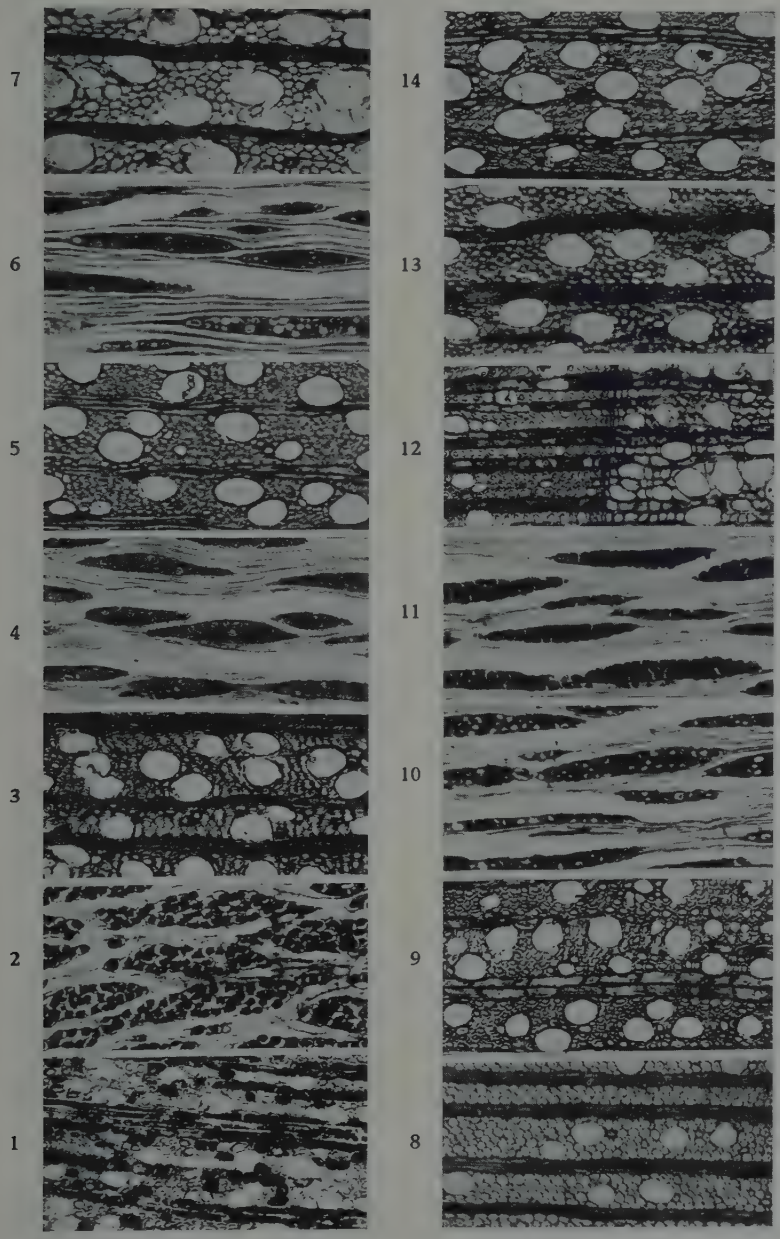
10). — Tangential longitudinal section through the E.M.II stock, budded to Delicious scion variety. The structure is typical of the stock.

11). — Tangential longitudinal section through the wood of the E.M.I stock, budded to Calville scion variety. The proportion of uniserial wood-rays is considerable. Their shape is not constant; sometimes oval and often asymmetrical.

12). — Transverse section through the wood of the Seedling stock, budded to Calville scion variety. The sharp transition between the spring and summer wood is noticeable. The number of vessels in spring wood is very high.

13). — Transverse section through the wood of the Calville scion variety, budded on the E.M.XVI stock. Fibrous tissue highly developed as a result of the influence imparted to it by the stock.

14). — Transverse section through the wood of Delicious scion variety, budded to the E.M.XVI stock. Fibrous tissue highly developed as a result of the influence imparted to it by the stock.



B. KOMAROFSKI — WOOD ANATOMY OF APPLES.

A NEW CLASS OF ASCOMYCETALES

A CONTRIBUTION TO THE ORBIS VITAE SYSTEM OF FUNGI

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I. INTRODUCTION

Throughout the decades of our mycological work we have considered biology as the basis not only of applied but also of systematic mycology. Descendental taxonomy always seemed to us to ignore the progressive development of fungi as revealed in their changes and adaptation in form and function. We have therefore long envisaged a completely different system of fungal taxonomy in which not descendental remnants of the past, but biological facts of the present, shall be our guide.

In 1937 we have formulated our ideas concerning this system as follows (9):

"In diesem System sollten die Organe nach ihrer Funktion und die Funktionen in ihrer Bedeutung fuer den Organismus und die Art definiert werden. Auch fuer die Stellung und Bedeutung von Art, Gattung und Gattungsgruppen in ihren gegenwaertigen Lebenskreisen sollen die erkennbaren Beziehungen und Funktionen zur umgebenden Natur im Zusammenwirken mit den uebrigen Organismen richtunggebend sein. Dieses Zusammenwirken, das sich als ein System von Lebenskreisen darstellt, duerfte nicht so sehr einen Kampf ums Dasein bedingen oder voraussetzen, vielmehr eine nach Gestalt und Funktion gegenwaertig erkennbare Erfuellung des gegebenen Lebensraumes. Waehrend in den gegebenen Lebenskreisen des Individuums, der Art und der Gattung sich die Erfuellung von Lebensaufgaben in engsten und engeren Kreisen darstellt, kommt in den Familien, Ordnungen und Reichen das Zusammenwirken hoeher und hoechster Lebenskreise in der Gesamtheit des derzeitigen Lebens mit der sie umgebenden Natur zum Ausdruck."

In short, we hold that the relations of an organism to its environment, and its functions in that environment, — which will here be referred to as the orbis vitae or life-sphere of the organism — should be considered significant in defining its systematic position, and that this principle is applicable not only to individual organisms but also to smaller and larger groups or classes of such organisms.

This system has gradually matured in our minds and has assumed its final shape in the course of our more recent work in Poland and the U.S.S.R. We have laid down the fundamental principles of such an orbis vitae system of fungi in a book we hope to be able to publish shortly (11).

In the present paper the whole problem of fungus taxonomy will be discussed in relation to two fungi we have studied at the research institute of the Polish Government Forestry Service, Warsaw. These two fungi, of which one is a species of *Ceratostomella* and the other a species of *Melanospora,* were isolated in pure cultures from

the black coating of some timber from deciduous trees at Bialystok in 1938, and were studied and drawn in detail. Unfortunately most of our material, together with the cultures, was lost in Warsaw when the Germans invaded Poland. We were left with only a few illustrations which will be presented here. We nevertheless hope that this paper, though not as complete as we would have wished it to be, may yet contribute to the clarification of the problems of fungus taxonomy with which we are concerned.

We have found it necessary provisionally to create new genera for the two fungi we studied, assigning the species of *Ceratostomella* to the genus *Fugascus* and the species of *Melanospora* to the genus *Lysascus*. This was done on the following grounds: (1) we wished to emphasize the peculiar biological characteristics of these types of fungi which are not common to all the species of the genera they have hitherto been included in; (2) we are of the opinion that, as explained below, these types are eventually to constitute new genera. It is, however, to be clearly understood that the new names are applied only provisionally and final decision on this point requires further exhaustive study.

Before proceeding with the discussion of our taxonomic conceptions we shall review the accepted principles of taxonomy. Basing on this review we shall develop our conceptions in the light of our observations on *Fugascus* and *Lysascus*.

As GAEUMANN (13) has published a comprehensive review of the more recent researches on the development of *Ascomycetes*, we shall mainly refer to him and refrain from quoting individually each of the many papers he has included in his review.

We herewith wish to express our warm gratitude to the Polish Government for enabling us to continue our work from 1936 to 1939 in the Forestry Research Institute at Warsaw, where many of the ideas presented here have taken shape.

II. TAXONOMY BASED ON PHYLOGENY

1. *Caryology and Phylogeny*

The cytological and caryological researches of the past 70 years have resulted in many important and revealing discoveries in this field of mycology. However, the numerous painstaking studies carried out in this direction have not succeeded in providing a satisfactory solution to the problems of the phylogeny and the systematic classification of fungi.

The facts established by these researches have eventually led to one conclusion: plasmogamy, caryogamy, and reduction, the three essentials of caryological ontogeny, and the various types of karyokinesis distinguished by the different courses taken by these processes, do not permit of any conclusions concerning progressive phylogeny, and these processes cannot be considered equivalent to the sequence

of generations of higher plants. On the contrary, the cytological data indicate a gradual retrogression of sexuality and of sexual organs.

This contrasts with the facts known concerning higher plants: here these two developmental processes run parallel to one another and have thereby acquired their phylogenetic significance.

The phylogenetic development of the fungal system has therefore during the past decades mostly been approached from a morphological, and not a caryological, aspect. The morphological consideration of organs on a phylogenetic basis has thus persisted as the fundamental principle of fungus taxonomy.

2. The taxonomic significance of the ontogeny of ascocarps

In the case of *Ascomycetes,* the phylogeny and taxonomy of which concerns us in this paper, this approach has resulted in the establishment of the following facts. Numerous studies [von Petrak, Theissen, Sydow, von Hoehnel, Arnaut, Corner, Miller and Nannenfeldt as quoted by Gaeumann (13)] have shown that an asco-locular and an asco-hymenial type of development may be distinguished in the formation of ascocarps of all families of the *Ascomycetes.* Based on the ontogenetic development of ascocarp structure in its early phase, this division requires the transfer of organisms with an asco-locular course of fruit formation from the hitherto accepted positions to the new, large group of *"Ascoloculares".* This may here be exemplified by discussing the fruiting body of *Mycosphaerella.*

This fruit, which has so far been considered and termed a perithecium, is now regarded as an "ascocarp"; what has previously been held to be its perithecial wall will now be considered a "conceptacle" (remnant of an earlier stroma); the "ostiolum" of this fruit now becomes a "porus", as it is neither preformed nor schizogenous in origin; the hymenium becomes a "pseudo-hymenium", because it originates in a closed loculus; and paraphyses, if any, will now be regarded as paraphysoid or interthecial hyphae (13).

This would lead us to conclude that *Mycosphaerella* can no longer be considered to belong to the (asco-hymenial) *Sphaeriales,* but must be transferred to the (asco-locular) *Pseudohymeniales.* The *Pseudohymeniales* could no longer be included in the *Pyrenomycetes,* but in the new class of *Ascocarpiomycetes.* The *Ascocarpiomycetes* would have to belong to the large new division of the *Ascoloculares.*

Now the genus *Mycosphaerella* comprises about a thousand different species classed into sections according to the type of secondary fructifications they produce. Members of these various sections have to be subjected to ontogenetic studies before they can be clearly divided into separate genera on the basis of the type of their fruit formation which is obscured as the fruits mature. Related genera of the *Euascomycetes* will likewise have to be investigated closely.

Gaeumann (13), who also favours this new taxonomy, has summed the position up as follows:

"Da die Systematik der *Euascomyceten* jetzt vorwiegend auf den Bau der Fruchtkoerper begruendet wurde, setzt numehr, aehnlich wie bei *Mycosphaerella,* mit steigender entwicklungsgeschichtlicher Erkenntnis eine Hin- und Rueckwanderung von Familien, Gattungen und Arten ein, deren Ende unsere Generation nicht mehr erleben wird."

GAEUMANN'S pessimistic view of the complications arising in the application of the new principle evidently has a twofold basis. In the first place, even microscopical examination of a fruit body cannot trace the course of its formation. Cytological study of the early phases of fruit development is possible only with special cultural facilities and by aid of a special technique with which a taxonomist working along the accepted lines of microscopical investigations is not usually conversant. Secondly, there is no means of determining the course of fruit formation in the established species which are at best available in dried herbarium specimens, and then never in the young stages of fruit formation. The taxonomist will therefore as a rule be unable to form his own opinion of the systematic position of the species he studies.

A third important consideration is that — even with all facilities for cytological and cultural studies — mycologists will not be able to deduce the phylogenetic origin of the various types of fruit formation now encountered. This is due to the fact that at best only remnants of the ancestral type can persist in so early a phase of ontogenetic development. Safe conclusions concerning the original type of fruit formation can be arrived at only where the present species, on reaching maturity, still indicate the parent type.

But even if we could correctly reconstruct the original type, this could only be a type of the past, with its forms and functions more or less completely changed in the course of its development, and there will be little evidence of the original life-sphere of this organism.

Little aid in the determination of present species or genera can be derived from such an original type because it has but slight connection with the form and function and the environmental relationships of the present fungus. The study of systematic relations can only be based on the forms and functions now apparent. For this reason the foundation of our taxonomy can only be in the present forms and in the relations based on these forms.

The union of types with ascolocular and ascohymenial fruit formations in the accepted system of species, genera, families, and classes thus fully corresponds to their present systematic relationships: their organs and fruits possess the same specific form and function, and they belong to the same life-sphere, although their ascolocular or ascohymenial ancestors may once have had different affinities and may have belonged to different life-spheres unknown to-day.

Why, then, were morphologists and taxonomists moved to agree to distinctions between genera, families, and classes so much alike in

their form, function and life-sphere, although the distinguishing criteria consisted of obscure remnants of former phases of existence incapable of further structural or functional development and of no value to the present existence of the organisms?

The sole reason would appear to lie in that now generally accepted principle of theoretical morphology and phylogeny, which was inaugurated by the theory of descendence and has been formulated by Eduard Strassburger (15) as follows:

"dass nur die gleiche Abstammung, nicht die gleiche Funktion, den morphologischen Wert eines pflanzlichen Gebildes bestimmen."

A further principle follows from the first, namely, that only homologous organs (of equal origin), possess equal morphological and taxonomic significance, while this cannot be said of analogous organs, i.e. those of equal function but distinct origin.

The acceptance of these principles has given decisive morphological and taxonomic importance to slight indications of the origin of an organism, though these may be of no account in its present existence. On the basis of such principles present types of equal form, function and life-sphere have been separated, to be grouped anew in accordance with insignificant remnant characters of their ancestors.

III. TAXONOMY BASED ON ORBIS VITAE

A. *General Principles*

Earlier studies (3, 4, 5, 6, 7, 8, 9), especially the still unpublished monographic study of *Ceratostomella* blue staining of coniferous timber (10) and a book on the principles of an orbis-vital taxonomy of fungi (11), have led us to new principles of morphological valuation and to a fresh systematic arrangement of fungi, which may be briefly outlined in the following three axioms:

1) The morphological valuation of an organ depends on various factors, of which similar present functions and similar present life-sphere relationships may be established experimentally beyond any doubt. These factors are therefore of overriding significance for the proper comprehension of the formation, development and systematic arrangement of now existent types of fungi.

2) The basic classes of fungi (characterized by the suffix "mycetes") are therefore distinguished, regardless of their origin, according to the form and function of their spore producing and spore dispersing organs, and according to their life-sphere relations to those environmental factors that ensure the dispersal of spores to their natural substrate.

3) Further division into lower groups (characterized by the suffix "aceae") may be based on homologous organs for spore formation in the ancestral types, regardless of present functions and life-sphere, provided such homologies can still be established with certainty.

1. *Criteria of distinction between classes of fungi*

In the commonly accepted classification of fungi the two major classes, the *Ascomycetes* and *Basidiomycetes*, are distinguished and named according to their organs for spore formation and dispersal. The appearance of these organs is so characteristic that mycologists have never seriously disagreed as to their significance as criteria of class distinction. But numerous studies and interpretations have not succeeded in elucidating the phylogenetic course of development and the homologous basic forms from which these organs have originated. Nevertheless attempts to indicate their phylogenetic derivation are being made in the present taxonomic systems of fungi (2, 12, 13).

BREFELD (2, 16), to whom we owe the clearest of these systems, derives the ascus from the sporangium of the *Phycomycetes*, and the basidium from the conidiophore of lower fungi. These derivations are no longer considered valid, but it would lead us too far afield if we were to discuss in detail the derivations now accepted and the arguments supporting them, especially as none of them is susceptible of unequivocal proof. On the other hand, BREFELD's (2) purely morphological characterisation of ascus and basidium have never been disputed and appears unassailable.

We wish to supplement and widen his morphological determinations by the aid of functional characteristics. For this purpose we shall first briefly review the definitions of the character of the ascus as laid down in our earlier papers (3, 4, 5, 6, 7, 8). We have denoted the ascus, from a functional aspect, as a spore discharge tube and have traced the causal relations between this function and the structural characters of the ascus.

Mycologists have been rather slow to recognize this function of the ascus. ZOPF (17), in 1887, may have been the first to follow the process of spore ejaculation in the transparent perithecium of the genus *Pleurage*. On reaching maturity, each of the asci in turn elongates, penetrates the orifice of the perithecium, and protrudes its tip beyond the latter, until the limits of the elasticity of the ascus membrane is reached and exceeded by the pressure within. At this juncture the tip of the tube is ruptured and ejaculation takes place of the chain of spores adhering to each other by a gelatinous appendage. The perithecium is only 0.5 mm high, but the height to which spores are catapulted into the air is stated to reach 15 cm in the case of *P. fimisada*, and even 45 cm(?) in the case of *P. curvicolla*.

With most of the active *Ascomycetes* ejaculation causes the spores to separate from one another and to disperse singly (4, 6, 7).

The asci of *Endothia parasitica* and of some *Gnomoniaceae* are, when maturing, severed from the base of the perithecium and are pressed into the canal leading to the orifice. When the fruit desiccates the asci are said to be compressed within the canal and the resulting lateral pressure aids spore ejaculation (12).

In the case of *Leptosphaeriaca acuta* [HODGETT, 1917 (12)] and in species of *Pleospora* [ATANASOFF, 1919 (12)], the ascus membrane is differentiated into a non-elastic, outer cuticular layer and a markedly elastic, inner mucous layer. The latter, expanding as maturity is reached, ruptures the outer layer, protrudes far beyond it and ejaculates the spores.

We particularly stress these differences in the mechanisms of spore ejaculation from the ascus, as it may be assumed that closer study will reveal further modifications of such mechanisms that may be of taxonomic value. The height to which spores are ejaculated and the amount of pressure created in the ascus before it ruptures may likewise be significant for spore dispersal and life-sphere relationships. Thus the spores of species of *Gyromitra* and *Morchella* may be assumed to be thrown only to a small height, sufficient to get clear of the chambers and canals of the fruit body and to be seized by air currents (5).

2. *Ascus and fruit characteristics of morphological and physiological significance*

From a structural and functional aspect we may thus distinguish three essential parts in each active ascus:

(1) The membrane effecting ejaculation.

(2) The epiplasm supplying the osmotic force required for spore ejaculation.

(3) The spores that are successively ejaculated from the mature ascus.

(1) The wall of an ascus consists of elastic membranes; when maturity is reached these are strongly extended by osmotic pressure and rupture at the apex — frequently at a predestined point— as soon as the inner pressure exceeds the limits of their elasticity. Once ruptured, the membrane contracts like the chord released from a bow, and simultaneously empties its spore content much as a sling contracts after the throw with lightning rapidity. In this process the ascus tube mostly separates the spores and ejects them singly, in rapid succession, from its terminal opening.

In the course of this action the ascus thus provides the spores it ejects with a certain amount of kinetic energy by which the spores are actively thrown, in a straight line, at a definite velocity and to a definite height, into the atmosphere beyond the upper side of the fruit. The height reached by spores on ejaculation is as a rule sufficient to ensure their being dispersed by air currents even though gravitation may cause them to lose some of this height before they are seized by the currents. Here the height gained by the spores is always such that dispersion is ensured, because the size (weight and surface) of the spores of each species is of an order facilitating their dispersal by the temperature currents prevalent during the vegetation period (8).

(2) No less important than the elasticity of the membrane is the osmotic efficiency of the intersporal substance of the ascus. Persisting as an amorphous plasmatic mass after spore formation, this substance at the onset of maturity is subject to molecular transformation to an osmotically potent medium generating the force required for spore ejaculation.

(3) In the ascus tube spores are formed by free cell division in pre-determined number, arrangement, form and size, and reach maturity in a sequence equally predetermined in time and space.

This is closely connected with the fixed caryological system of spore formation. Cessation of vegetative growth and inception of the fructification process may be brought into relation with the caryogamic union of the hereditary mass of two vegetative nuclei. Similar relations may be established for the reduction of spore size and weight — by reduction division — to the minimum conducive to spore dispersal by delicate air currents or to contagion by other means. All the remaining morphological and physiological characters may likewise be related to the life-sphere relationships peculiar to the various species, genera etc.

As mentioned above, the arrangement of asci in the perithecium itself is of a definite spatial order, and the ripening, mounting of inner pressure, elongation, and ejaculation of asci takes place in predetermined sequence. The spatial arrangement has the physiological effect that the tip of each ascus, in maturing, widens towards the perithecial orifice, protrudes beyond the latter and discharge its spores in a similarly pre-determined direction. The succession in time of the maturation of asci results in each ascus in turn reaching maturity and discharging its spores, so that the perithecium as a whole — as a collective ascus of a higher order — continuously discharges single spores. The structure and function of such perithecia is so delicately precise that it may be termed a "precision organism". In its manifold variations it represents the climax of a progressive morphological and functional course of development in this particular direction.

3. *Taxonomic significance of morphological, functional and life-sphere characters of ascus and fruit*

From all the above emerges the fact that the common characteristic of all *Ascomycetes* is the active ascus, the morphological value of which can neither be understood nor defined without previous knowledge of its functional character.

In structure, the ascus has been seen to be a spore tube for the endogenous formation, in a definite caryological course of development involving caryogamy and reduction, of a number of spores (limited to two, four, eight or sixteen) produced in pre-determined spatial arrangement and sequence.

In function, the ascus has been shown to be a spore discharge tube ejaculating the spores formed in it with a definite amount of

kinetic energy, and in a definite direction. The spores are discharged into the atmosphere singly, mostly in quick succession, so that the dispersal of each spore by air currents is ensured.

The taxonomic significance of these characteristics will be demonstrated in this paper, in contrast to the hitherto accepted systematic principles basing only on morphological features, by discussing two species we have studied, one of *Melanospora* and one of *Ceratostomella* (*Ophiostoma*). These, as mentioned above, will now provisionally be referred to the genera *Lysascus* and *Fugascus*, respectively.

We shall now proceed to examine the structure, physiological nature and life-sphere of these proposed new genera in the light of the princples enunciated above.

B. *The genera Fugascus and Ceratostomella*

Both these genera belong, according to the accepted taxonomy, to the class of *Ascomycetes*. The genus *Fugascus* and the whole family of the *Ceratostomellaceae* have previously been placed into the subclass of *Pyrenomycetes*, where they were included in the order of the *Sphaeriales* (12).

In the genus *Fugascus* and the species of *Ceratostomella* even the morphological character of the ascus has undergone important changes. From a cytological aspect, the following differences deserve special mention (1):

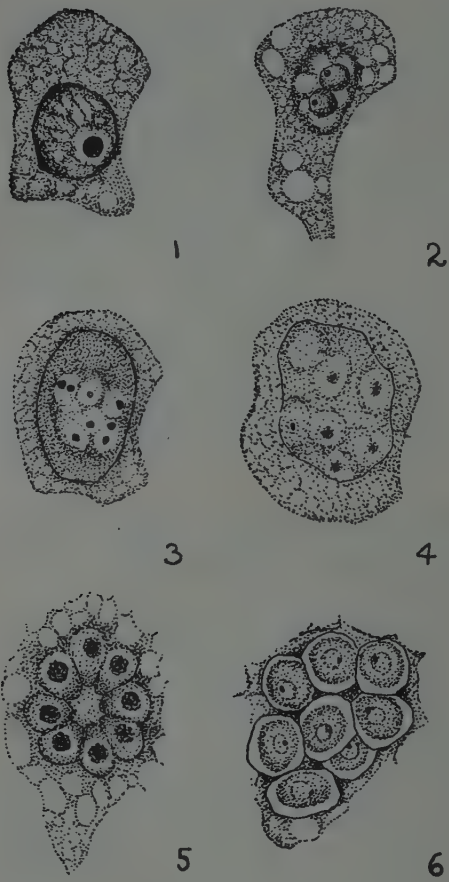
The dicaryon mother cell grows into a parenchymatous, ascogenous tissue, so that ascogenous hyphae are lacking altogether.

The ascogenous cells and mature asci possess only one plasmatic membrane. All phases of the development of a firm and elastic ascus membrane are thus lacking.

The spores are formed simultaneously as protuberances of a central lump of plasm. They subsequently form a compact group of 8 spores, the "octophore" (text-fig. 1), in which they are arranged like the segments of an orange fruit. The shape of the spores then becomes rounder, and all eight of them rest for a short time irregularly arranged, enveloped by the plasmatic membrane (text-fig. 1), but even this loose connection soon terminates. It is only during this short period in which the spores rest together that any similarity to an ascus can be recognized. Later the multitude of all spores, irregular in configuration and embedded all round by plasmatic mucus, fills the whole of the cavity of the ascocarp.

Only in the genus *Fugascus* the spores retain the shape of orange segments so clearly that the octophore can be reconstructed from a single spore. This is shown in text-figures 2A and 2B. Figure 2C represents microscopic views of a single spore in lateral, dorsiventral and transverse section.

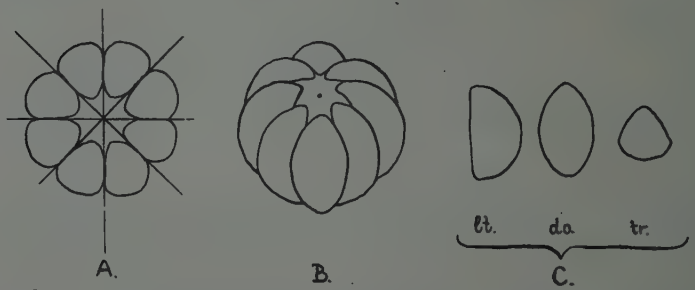
The most important features of this spore formation process are, from a morphological point of view, the entire absence of an



Text-fig. 1.

Ceratostomella fimbriata Nannf. Development of the ascus tube (x 3000). After ANDRUS and HARTER (1).

1) Primary nucleus.
2) Binucleate stage.
3) and 4) Octonucleate stage with endogenous wall.
5) Octophore stage.
6) Mature, naked spore tube. The spores are spherical, liberated from the octophore resembling the ancestral ascus.



Text-fig. 2. — Diagrammatic representation of the octophore of *Fugascus*: A) transverse section, B) lateral view, C) individual spores of *Fugascus*, lt.=lateral view, dv.=dorsiventral, tr.=transverse section (x 800).

ascus membrane, the very early dissolution of individual asci, and the irregular distribution of spores in the perithecium. Even in their early phases these features are quite unlike the morphological development in active perithecia.

The complete loss of the function of an ascus, as described above, is so outstandingly important for morphological definition, that the spore tube of *Fugascus* and of many *Ceratostomellaceae,* representing only a brief and transient phase, can no longer be termed an ascus. *Fugascus* and the *Ceratostomellaceae* showing these features must consequently no longer be included in the *Ascomycetes.*

If we trace the further course of the development of the perithecium of *Fugascus,* we note that at a certain stage of maturity the spore mucus exudes through the long perithecial beak and persists at its tip in something like a drop. The mucus is held together in this way by the circle of cilia singly arranged on the ostiole. These prevent the lateral escape of the mucus. We propose to term this new structure a "haerangium", and to unite in the new class of *Haerangiomycetes* all those species hitherto included in the *Ascomycetes* that exhibit this type of spore formation process. The haerangium represents a new organ of present spore formation and dispersal which shall serve as the basic criterion for the creation of a class, in much the same way as the ascus and basidium.

The morphological characters distinguishing *Fugascus* and *Ceratostomella* from genuine active *Ascomycetes* may be described as follows:

1) The spores of *Fugascus* differ from those of active *Ascomycetes* in their shape. This, as stated above, resembles the shape of the segments of orange fruits. Similar spore shapes likewise appear at certain phases of spore formation — but not apparently at maturity — in the genus *Ceratostomella.* This shape is derived from the peculiar mode of spore formation in *Fugascus* and *Ceratostomella.*

2) This mode of spore formation, the "octophore", also represents a distinct morphological character in the development of *Fugascus* and *Ceratostomella.*

3) No ascus membrane, or remnant of such membrane, is being formed. After their formation in the octophore the spores are enveloped only by a plasmatic membrane. Only the fact that during a short period groups of 8 spores are held together by one such membrane is still reminiscent of ascus tubes and explains why mycologists still include the *Ceratostomellaceae* in the *Ascomycetes.*

4) The rostrum, replacing the perithecial beak and ostiole of the active *Pyrenomycetes,* grows to such a length that the elastic force of an ascus would be insufficient for the ejaculation of spores beyond the ostiole.

5) The tenacle. A circle of cilia forms around the ostiole, diverges at maturity and serves to collect the mucus exuding from the rostrum in a tenacle preventing the lateral dripping off of such mucus.

6) The haerangium. Collected and contained by the tenacle, elevated and supported by the rostrum, there forms a drop-like conglomeration of spores, which we have termed "haerangium"; the spores are glued together by plasmatic mucus and some of them adhere to firm bodies on contact.

The haerangium represents a novel organ for the storage and dispersal of spores and constitutes, just like the spores and octophore, a fundamentally new and distinct type.

The physiological characteristics of *Fugascus* and the *Ceratostomellaceae* likewise deviate essentially from those of the active *Ascomycetes* and are closely linked with the new morphological type. These characteristics may be described as follows:

1) There is no spore ejaculation tube, no elastic ascus membrane, no osmotically potent epiplasm.

2) The epiplasm is capable of swelling only to an extent sufficient to cause the spore mucus, which is irregularly disposed about the cavity of the ascocarp, to exude through the rostrum on to the tenacle, where it collects to form the haerangium.

3) The spores are not ejected singly. They cohere through sticky mucus and remain on the tenacle until they adhere to the organs of certain insects that serve to spread them.

4) Spore dispersal is thus preferably effected by passive adhesion to definite substrates to which the spores cannot be carried by temperature or wind currents.

The above morphological and physiological distinctions are, of course, closely related to the life-sphere peculiar to *Fugascus* and the *Ceratostomellaceae*. The special features of this orbis vitae may be characterized as follows:

(a) The substrate peculiar to these fungi is the living wood, covered by bark, of felled or physiologically weakened conifer trees. Only *Ceratostomella ulmi* (BUISMANN, 1932) attacks and kills healthy trees.

(b) Spore dispersal, as already mentioned, is effected by the agency of flying insects which frequent trees of the above type and transmit the spores directly into the bark and wood.

In the above we have outlined the characteristics common to the genus *Fugascus* and many *Ceratostomellaceae* and distinguishing them from the *Ascomycetes*. We may now proceed to discuss the features distinguishing this genus from the *Ceratostomellaceae*.

1) The species of *Ceratostomella* preferably attack conifer wood, while *Fugascus* has so far been observed on the wood of deciduous trees only.

2) The vegetative mycelium of the species of *Ceratostomella*, after concluding the assimilation of food, assumes a dark colour especially where exposed to the air and thus causes the blue discoloration of conifer wood. On the other hand, the vegetative mycelium of *Fugascus* remains colourless and causes neither blue staining nor darkening of affected wood. In view of the practical importance of the *Ceratostomellaceae* as the agents of the blue staining of timber, this characteristic appears significant.

3) The spores of *Fugascus* retain at maturity the shape they have assumed in the octophore, i.e. that of the segment of an orange fruit; as apparent from text-fig. 2, each such mature spore may serve for the reconstruction of the structure of the whole octophore.

4) Further features distinguishing *Fugascus* from the *Ceratostomellaceae* are the size of perithecium and spores and the fact that in the former the parallel hyphal bundles forming the rostrum diverge at the passage of spores, so that each individual spore can be observed while passing this tube (cf. text-fig. 3).

Text-fig. 3.

Fugascus. Upper part of the rostrum, showing the spores exuding singly. The cilia of the tenacle support the haerangium (x 300).

Detailed studies will have to decide whether or not these distinctions suffice for the creation of a separate genus, or perhaps only subgenus, for the fungus here provisionally designated as *Fugascus*.

C. *The genera Lysascus and Melanospora*

According to all its characteristics *Lysascus* belongs to the genus so far known as *Melanospora* in the family *Melanosporaceae*, a subdivision of the *Pyrenomycetes* with an ascohymenial type of fruit formation. This family probably still comprises forms possessing active asci and perithecia. The question, whether the asci are active, has hitherto appeared so unimportant that it has not been studied closely and we are not aware of detailed literature on this subject. We shall base on the assumption that the family of the *Melanosporaceae* comprises active as well as inactive types, and propose to separate the latter from the former by placing them into the genus *Lysascus*, as distinct from *Melanospora*. We suppose that further species of *Lysascus* and its type occur and these may be considered to form the family of the *Lysascaceae*. The *Lysascaceae* belong neither to the *Pyrenomycetes* nor to the *Ascomycetes*, but to the new class of *Haerangiomycetes*, just like *Fugascus* and the *Ceratostomellaceae*. The reasons leading us to this view will be described in the following paragraphs.

The ontogenetic development of *Lysascus* is represented by text-figures 4-5, and is explained in some detail in the legend to these figures. Just like ZOPF (17) who has followed the course of active spore ejaculation in the transparent perithecium of *Pleurage*, we have traced the course of the formation and dissolution of the ascus in the transparent perithecial fruit of *Lysascus*.

Text-figure 4 shows that the orientation of the asci, basing on the inner perithecial base, is towards the orifice of the perithecium. All stages of maturity of asci and spores are present at this juncture, so that the fruit then still exhibits all the characters of perithecia of active *Pyrenomycetes*.

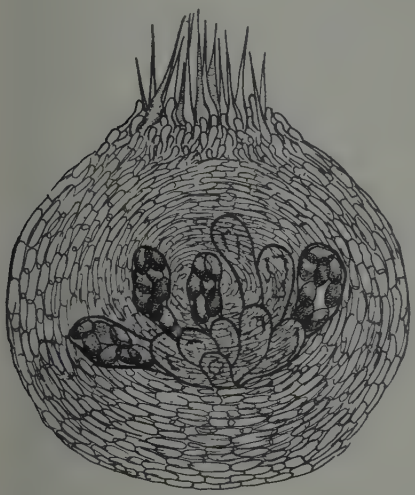
But in a later stage the entire perithecial cavity is filled by mature spores embedded irregularly in sticky plasmatic mucus, much like those in the perithecia of the *Ceratostomellaceae*. The cilia encircling the ostiole begin to diverge and the spore membrane is reinforced by longitudinal thickenings and is coloured dark brown.

In text-figure 5 most of the spores are seen to have exuded from the ostiole and to be imposed upon the circle of diverting cilia as a typical haerangium.

All the morphological features characterising the active ascus, i.e. the shape, number and arrangement of spores, the shape and arrangement of asci, and the perithecium with its shape, short neck and ostiole, are still present in the first phases of fruit formation in

Lysascus. Nevertheless, its inclusion in the class of *Haerangiomycetes* is warranted on the following grounds:

The ascus membrane has lost its characteristic elasticity and the epiplasm its osmotic potency. Moreover, the ascus membrane dissolves at maturity and the spores, irregularly embedded in swelling plasmatic mucus, fill the perithecial cavity. The spores are not ejaculated singly, but, when mature, exude from the ostiole adhering to one another. The spores, held by a tenacle of cilia and supported by the perithecial base, form a haerangium, from which they are dispersed to their substrates by adhering to animal vectors. For these reasons *Lysascus* belongs into the class of *Haerangiomycetes* together with *Fugascus* and the *Ceratostomellaceae*, though its relation to the *Ascomycetes* is still a close one while that of these latter fungi is much more distant.



Text-fig. 4.

Lysascus. First stage: Ascocarp spherical, containing fundaments of asci. Cilia of the tenacle converge (x 600).

Text-fig. 5.

Lysascus. Stage of maturity, showing haerangium. The diverging cilia form the tenacle supporting the haerangium (x 300).

In our orbis vitae system of fungi *Lysascus* is of twofold significance. It demonstrates the transition from the type of active *Pyrenomycetes* to that of passive *Haerangiomycetes*. It further shows the course of the retrogressive development from the active ascus to the passive haerangium which subsequently leads to the characteristics observed in *Fugascus* and the *Ceratostomellaceae*.

The latter fungi on the one hand, and *Lysascus* on the other, thus represent two distinct sub-groups of ascus derived or asco-degenous *Haerangiomycetes* which may be defined as asco-proxal and asco-distal *Haerangiaceae,* respectively.

IV. DISCUSSION AND CONCLUSIONS

1. *The taxonomic valuation of retrogressive developments*

Fugascus and *Lysascus* are considered to derive from the active *Ascomycetes* on account of the hereditary resemblance of their ascus formation. In these fungi the morphological characteristics of asci can still be recognised, though the asci have long since lost their spore dispersing function, and thus their orbis-vital significance, as well as important structural traits.

In *Fugascus* and the *Ceratostomellaceae* the ascus structure fails to persist at maturity and is discernible only in the course of the ontogenetic development of the fruit, and even then only at a definite, rapidly transient phase. The derivation of these fruits from active asci can be maintained only owing to the discovery of the intermediate type of *Lysascus,* where the origin of the fruit from active asci and perithecia cannot be doubted.

As in the case of *Lysascus,* we have been able to show for numerous inactive *Ascomycetes* and *Basidiomycetes* that they have originated, and developed retrogressively, from higher to lower types of fruiting bodies with structural and functional changes in their fundamental organs for spore dispersal (11). Though restricted to fulfilling the task of spore formation only, and though phylogenetically far removed from their ancestor types, the hereditary roots of the present types of fruit bodies are nevertheless so clearly evident in their ontogenetic development that mycologists have continued to class these fungi together with those that have retained the fruit structure and functions and the life-sphere of the common ancestors.

In their retrogressive development the original structure and functions of spore dispersal organs have, over an equally long period of development, been replaced by new structural and functional types. These, though less elaborate, appear to suit the present life-sphere relationships of their fungi as perfectly as the original type suits the fungi that have still retained it. In the accepted descendental taxonomy the criterion of morphological valuation and systematic classification has thus been the homologous ancestral organ, — what was deemed to be the ascus, — although this has long since lost its functions and has been replaced by a new basic organ for spore formation and dispersal, the haerangium, which in form and function closely fits the present life-sphere.

In our new orbis-vital taxonomy we have, therefore, distinguished *Lysascus, Fugascus* and the *Ceratostomellaceae* from the

Ascomycetes and have created for them the new class of the *Haerangiomycetes* based on their present organs for spore dispersal.

2. *The taxonomic valuation of progressive developments*

As we have seen, the accepted principles of descendental taxonomy have caused the systematic importance of homologous organs to be overemphasized, and have led to taxonomic distinctions between types closely related in all but some early phase of their ontogenetic development, e.g. between *Ascoloculares* and *Ascohymeniales.*

In our orbis-vital system the fungi that have progressively developed to the highest types of active *Ascomycetes* will be united in the same class, family and genus, regardless of the fact that their fruit formation may have taken an ascolocular or an ascohymenial course. In our system homologous ancestral forms are no longer considered to possess overriding significance in the morphological valuation and the classification of fungi, because these forms have lost their earlier functions and life-sphere and have been regrouped into new structural and functional types fitting the new conditions of their existence.

3. *The course of phylogeny in the Ascomycetes*

The above progressive and retrogressive developments in the *Ascomycetes* indicate the regular occurrence of the following processes:

(1) Fungi originally distinct in their type of fruit formation (ascolocular and ascohymenial) may progressively arrive at a common basic type of spore formation and spore dispersal of the highest order.

(2) Intermediate types are continually being superseded in this process, so that evidence of ancestral hereditary features may persist only in the earliest ontogenetic phases of fruit formation.

(3) On the other hand, the retrogressive development of uniform ancestral types of the highest developmental order has led to the formation of a multitude of structural and functional types of a lower order of development.

(4) All the stages of this retrogressive phylogenetic development are reflected in structural types, type remnants, or intermediate types, which must be considered the most valuable evidence of their developmental history.

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ON THE OCCURRENCE, MORPHOLOGY AND PARASITISM OF *SCLEROTIUM BATATICOLA*

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(With plates I and II)

I. INTRODUCTION

The experimental part of the investigations presented in this paper was carried out in 1927/1928. A note summarizing the results of immediate practical interest concerning beans was published in 1928 (105). Publication of the detailed data of this work has had to be delayed, and they are now presented in the light of the researches since carried out on *Sclerotium bataticola* in various countries, and especially in the U.S.A.

The problem confronting us when this work was initiated was chiefly the determination of the parasitic vigour of the various isolates of *S. bataticola* obtained from a number of hosts in Palestine. In this connection, two questions required elucidation.

(1) Are all the isolates of *S. bataticola* pathogenic on the hosts with which they are associated?

(2) Do these isolates differ from one another in respect of their morphology, physiology, or pathogenicity?

Little experimental data relating to the infection of plants by *S. bataticola* have been added, during the 20 years since the conclusion of our experiments. In most of the more recent work, inoculation with *S. bataticola* was carried out with isolates that may have originated in geographically distant localities but were derived from a limited number of hosts only. Our studies record the results of inoculations with isolates from ten different hosts on five of the hosts.

Our knowledge of the morphology of the fungus has advanced even less. Nothing has been added to the first description of sclerotial formation given by BUTLER (24), who in his turn had certainly used some of SHAW's (112) data. Unfortunately the latter author's paper was not available to us. The description of sclerotial formation given by UPPAL et al. (144) is mostly based on BUTLER. However, UPPAL et al. were the first to draw attention to the differential growth made by two strains of the fungus when grown on agar in Petri dishes. In our work special attention was paid to morphological, cultural and pathogenic characters of the above mentioned isolates from ten hosts.

The taxonomy and nomenclature of *S. bataticola* are discussed and certain sub-groupings suggested in accordance with the results of our studies.

An up-to-date review of the plants attacked by *S. bataticola* in the various countries of its occurrence has been compiled and is presented here to indicate the host range as well as the geographical and ecological range of this fungus. A distribution map has also been drawn for this purpose.

II. NOMENCLATURE

The fungus *Sclerotium bataticola*, first described and named by TAUBENHAUS (135), has ever since 1925 (17) usually been referred to as *Rhizoctonia bataticola* (Taubh.) Butler. Later, when ASHBY (10) discovered the connection between the pycnidial and sclerotial stages, the name *Macrophomina phaseoli* (Maubl.) Ashby was accepted by some investigators in agreement with the rule that the imperfect form of a fungus should be referred to by the name of its perfect form. In 1937, HENSON and VALLEAU (50) opposed the use of the name *Rhizoctonia bataticola* on the grounds that (a) the latter genus has frequently been shown to be the imperfect form of a basi-

diomycete, whereas *Rh. bataticola* with its pycnidial stage cannot be considered as such, and (b) real clamp connections have never been observed in *Rh. bataticola*. These authors proposed the resumption of TAUBENHAUS' name *Sclerotium bataticola* for the sclerotial strains of the fungus. But their wise counsel has not been followed by all investigators, and the name *Rhizoctonia bataticola* (Taub.) Butler continues in use for the sclerotial strains or is at best replaced by the name given the pycnidial strain, *Macrophomina phaseoli* (Maubl.) Ashby.

In our view, for the reasons expounded by HENSON and VALLEAU, the name *Rhizoctonia bataticola* should never be applied to sclerotial strains of the fungus, nor should these be referred to solely by ASHBY's name for the pycnidial strain. The latter name, *Macrophomina phaseoli*, should be reserved for strains forming only pycnidia. On the other hand, strains forming only sclerotia and no pycnidia should be known by the name originally applied to the sclerotial form, viz. *Sclerotium bataticola* Taubh. This is in agreement with KENDRICK's (61) opinion, who opposed the name *Macrophomina phaseoli* when only the sclerotial stage is found.

There remain the cases in which both sclerotia and pycnidia are formed. To include these under either of the above names would perpetuate the present confusion. Thus a student of this fungus, when looking up references in the Review of Applied Mycology which accepts ASHBY's name *Macrophomina phaseoli*, can never know whether either the pycnidial or the sclerotial forms alone or both forms together are being referred to. To remedy this confusion we suggest that the strains forming both sclerotia and pycnidia should be designated as *Macrophomina* (*Sclerotium*) *phaseoli* (Maubl.) Ashby, i.e. that the form-genus *Sclerotium* should be included and bracketed between the generic name *Macrophomina* and the specific name *phaseoli*.

III. HOST AND DISTRIBUTION RANGE

The host and distribution range of *Sclerotium bataticola* has widened enormously since the fungus was first described in 1913 (135). In 1930, the first named author published a list of about 35 hosts which had been found affected by the disease in Palestine (100). Today, the hosts affected by this disease number 118 in Palestine and 132 in all countries of its occurrence as will be seen from Table I.

By 1930 the disease had been reported, apart from Palestine, from 21 countries, in South-East Asia and its islands, in Australia, Africa, North and Central America. It has since spread to, or has been discovered, in additional localities in these regions and in Southern Europe, South America and Canada.

Table I summarizes the reports on the occurrence of *S. bataticola* in various countries, arranged alphabetically according to host names, accompanied by the more important sources of each record. A distribution map of *S. bataticola* is presented in text-figure 1 (p. 121).

TABLE I

Occurrence of Sclerotium bataticola recorded on host plants in various countries

Host	Country	Author
Acacia decurrens	Ceylon	Small, W. (116)
— *elata*	Ceylon	Small, W. (118)
— *melanoxylon*	Kenya	McDonald, J. (79)
Acalypha Wilkesiana	Palestine	Reichert, I. (103)
Acer sp.	U. S. A.	Davis, W. C., et al. (35)
Albizzia sp.	Java	Steinmann, A. (131)
— *falcata*	Sumatra	Steinmann, A. (131)
— *moluccana*	Ceylon	Small, W. (121)
	Uganda	Small, W. (114)
— *stipulata*	Uganda	Small, W. (114)
Allium sativum (garlic)	U. S. A. (Texas)	Smith, H. P. (129)
	Palestine	Reichert, I. (100)
Amherstia nobilis	Ceylon	Small, W. (121, 125)
Annona muricata	Ceylon	Small, W. (116, 125)
— *squamosa*	Ceylon	Small, W. (125)
Antirrhinum majus	Palestine	Reichert, I. (100)
Apium graveolens	Palestine	Reichert, I. (105)
Arachis hypogaea (groundnut)	Bulgaria	Kovachevsky, I. C. (63)
	Burma	Su, M. T. (132)
	Gambia	Brooks, A. J. (23)
	India	McRae, W. (81)
	Kenya	McDonald, J. (80)
	Uganda	Hansford, C. G. (47)
	U.S.A. (N. Carolina)	Anon. (4)
	U.S.A. (S. Carolina)	Prince, A. E. (96)
	U.S.A. (Alabama)	Wilson, C. (164)
	Palestine	Reichert, I. (103)
Aralia filicifolia	Ceylon	Small, W. (117)
— *japonica*	Palestine	Reichert, I. (103)
Areca catechu	Ceylon	Small, W. (127)
Artocarpus integrifolia	Ceylon	Small, W. (126)
Asparagus sp.	Palestine	Reichert, I. (103)
Aster sp.	Palestine	Reichert, I. (103)
	Uganda	Small, W. (114)
Aucuba sp.	Palestine	Reichert, I. (103)
Begonia Rex bulbosa	Palestine	Reichert, I. (100)
Begonia tuberhybrida	U.S.A. (California)	Tompkins, C. M. (140)
Beta vulgaris	Morocco	Barbier, A. M. (11)
	Palestine	Reichert, I. (100)
	U.S.A. (California)	Tompkins, C. M. & Gardner, M. W. (141)
Bixa orellana	Uganda	Small, W. (126)
Borassus flabellifer	Ceylon	Small, W. (124)

TABLE I (continued)

Host	Country	Author
Brassica oleracea v. botrytis	Palestine	Reichert, I. (103)
— *rapa* (turnip)	Sierra Leone	Deighton, F. C. (36)
Buddleia variabilis	Palestine	Reichert, I. (103)
Cajanus sp.	India	Ashby, S. F. (10)
	Ceylon	Haigh, J. C. (45)
Callistephus sp.	Palestine	Reichert, I. (103)
	Uganda	Small, W. (125)
Capsicum annuum	Canada	Conners, I. L. (28)
	Ceylon	Small, W. (117, 125)
	Palestine	Reichert, I. (99)
		Reichert, I. & Hellinger, E. (105)
	U.S.A.	Martin, W. H. (75)
	U.S.A. (Georgia)	Higgins, B. B. (51)
Carica papaya	India	Uppal, B. N. (143)
	Palestine	Reichert, I. (103)
	Sierra Leone	Deighton, F. C. (37)
— *quercifolia*	Palestine	Reichert, I. (103)
Cassia floribunda	Tanganyika	Wallace, G. B. (152)
Casuarina sp.	Palestine	Reichert, I. (99, 100)
— *equisetifolia*	Uganda	Small, W. (120)
Catalpa sp.	Palestine	Reichert, I. (103)
	U.S.A	Hoffmaster, D. E., et al. (53)
Cedrus sp.	U.S.A. (south)	Hoffmaster, D. E., et al. (53)
Ceratonia siliqua	Palestine	Reichert, I. (103)
Chamaecrista procumbens	U.S.A. (Alabama, Georgia)	Weimer, J. L. (158)
Chamaerops sp.	Palestine	Reichert, I. (99, 100)
	Australia	Anon. (7)
	Greece	Sarejanni, J. A., & Cortzas, C. B. (106)
Cicer arietinum	India	Dastur, J. F.
	Palestine	Reichert, I. (103)
Cinchona sp.	Java	Steinmann, A. (131)
	Sumatra	Leffmans, S. (67)
Citrullus vulgaris	U.S.A. (Texas)	Young, P. A. (165)
Citrus sp.	Greece	Sarejanni, J. A., & Cortzas, C. B. (106)
	Tanganyika	Wallace, G. B. (152)
	U.S.A. (California)	Tompkins, C. M., & Gardner, M. W. (141)
— *aurantifolia* (lime)	Ceylon	Small, W. (116, 125)
	Dominica	Briton-Jones, H. R. (22)
	Palestine	Reichert, I. (100)

Table I (continued)

Host	Country	Author
Citrus aurantium (sour orange)	Ceylon	Small, W. (125)
	Palestine	Reichert, I. (99, 100)
— *limon* (lemon)	Palestine	Reichert, I. (103)
	Palestine	Reichert, I. (103)
	S. Rhodesia	Hopkins, J. C. F. (58)
— *sinensis* (orange)	Brazil	Fawcett, H. S., & Bitancourt, A. A. (41)
	Ceylon	Small, W. (116)
	India	Padwick, G. W. (89)
	Palestine	Reichert, I. (99, 103)
	S. Rhodesia	Hopkins, J. C. F. (55)
Clitoria cajanifolia	Uganda	Small, W. (116, 125)
Cochlearia armoracia	Palestine	Reichert, I. (103)
Cocos nucifera	Brazil	Bondar, J. (13)
	Ceylon	Small, W. (116)
	Trinidad	Briton-Jones, H. R. (21)
Codiaeum sp.	Uganda	Small, W. (114)
Coffea arabica	Belgian Congo	Anon. (5)
	Java	Steinmann, A. (131)
	Kenya	McDonald, J. (78)
	Tanganyika	Wallace, G. B. (154)
	Uganda	Small, W. (126)
— *robusta*	Ceylon	Small, W. (121)
	Uganda	Small, W. (125)
Colutea arborescens	Palestine	Reichert, I. (103)
Corchorus sp.	Ceylon	Small, W. (122)
	Formosa	Sawada, K. (108)
	India	Shaw, F. J. F. (113)
	Trinidad	West, J., & Stuckey, W. R. (160)
Coriandrum sativum	India	Thomas, K. M. (138)
Coronilla glauca	Palestine	Reichert, I. (103)
Cosmos sulphureus	Sierra Leone	Deighton, G. C. (39)
	U.S.A. (Texas)	Young, P. A. (165)
Cotoneaster Francheti	Palestine	Reichert, I. (103)
Crotalaria sp.	Ceylon	Small, W. (127)
— *juncea*	India	Prasad, N. (94)
— *intermedia*	U.S.A. (Texas)	Weimer, J. L. (157)
— *spectabilis*	U.S.A. (Texas)	Weimer, J. L. (157)
Cucumis melo	Chile	Wiant, J. S. (162)
	Palestine	Reichert, I. (100)
	U.S.A. (Iowa)	Young, P. A. (165)
— *sativus*	Palestine	Reichert, I. (100)
Cucurbita pepo	Palestine	Reichert, I. (99, 100)
Cupressus Benthami	Uganda	Small, W. (125, 114)
— *Lawsoniana*	Ceylon	Small, W. (123)
— *Lindleyi*	Ceylon	Small, W. (127)

TABLE I (continued)

Host	Country	Author
Cupressus macrocarpa	Ceylon	Small, W. (125, 118)
	Uganda	Small, W. (125)
— *sempervirens*	Palestine	Reichert, I. (99, 100)
Cyamopsis psoraloides	India	Prasad, W. (94)
Cydonia oblonga	Palestine	Reichert, I. (103)
Cyperus distans	India	Varada Rajan, B. S., & Patel, J. S. (146)
Dahlia sp.	Ceylon	Small, W. (123)
	U.S.A. (S. Carolina)	Post, Th. (93)
— *variabilis*	Palestine	Reichert, I. (103)
	Portugal	Post, Th. (93)
Daucus carota	Palestine	Reichert, I. (100)
Derris elliptica	Malaya	Thompson, A. (139)
Dianthus barbatus	Palestine	Reichert, I. (103)
— *caryophyllus*	Palestine	Reichert, I. (103)
Dimorphotheca sp.	Palestine	Reichert, I. (103)
Diospyros Kaki	Palestine	Reichert, I. (103)
— *virginiana*	Palestine	Reichert, I. (103)
Dolichos biflorus	India	Likhite, V. N. (69)
	Uganda	Small, W. (125)
— *lablab*	Tanganyika	Wallace, G. B.(151)
Elettaria cardamomum	Ceylon	Small, W. (126)
Eriobotrya japonica	Palestine	Reichert, I. (103)
Erythrina indica	Uganda	Small, W. (114, 125)
— *lithosperma*	Ceylon	Small, W. (116)
— *umbrosa*	Uganda	Small, W. (114, 125)
— *velutina*	Uganda	Small, W. (114, 125)
Eucalyptus sp.	Ceylon	Briton-Jones, H. R. (18)
	Palestine	Reichert, I. (103)
	Uganda	Small, W. (114)
— *globulus*	Uganda	Small, W. (114, 125)
— *rostrata*	Rhodesia	Hopkins, J. C. F. (54)
Ficus elastica	Palestine	Reichert, I. (103)
— *nitida*	Palestine	Reichert, I. (103)
Fragaria grandiflora	Palestine	Reichert, I., & Hellinger, E. (105)
	U.S.A. (California)	Tompkins, G. M., & Gardner, M. W. (141)
Garcinia mangostana	Ceylon	Small, W. (123)
Geranium sp.	Palestine	Reichert, I. (103)
Gladiolus sp.	Palestine	Reichert, I. (103)
Glycine soja	Canada	Hildebrand, A. A., et al. (52)
	Ceylon	Paul, W. R. C. (90)
	India	Likhite, V. N. (69)
	Palestine	Reichert, I. (100)

Table I (continued)

Host	Country	Author
Glycine soja (continued)	S. Rhodesia	Hopkins, J. C. F. (57)
	Tanganyika	Wallace, G. B., & Wallace, M. M. (155)
	U.S.A. (Illinois)	Tehon, L. R., & Boewe, G. H. (136)
	U.S.A. (Texas)	Young, P. A. (165)
Gossypium sp.	Belgian Congo	Brixhe, A. (16)
	Egypt	Briton-Jones, H. R. (17)
	Greece	Sarejanni, J. R., & Cortzas, C. B. (106)
	India	Likhite, V. N. (69)
	Nigeria	Jones, G. H. (59)
	Nyassaland	Anon. (2)
	Palestine	Reichert, I., & Hellinger, E. (105)
	Sudan	Andrews, F. W., & Clauston, T. W. (8)
	Trinidad	Briton-Jones, H. R. (19)
	Turkey	Bremer (15)
	Uganda	Small, W. (116, 119, 125)
	U.S.A. (Virginia, S. Carolina, N. Carolina, Tennessee, Georgia, Alabama, Mississippi, Louisiana, Texas)	Miller, P. R. (85)
	U.S.A. (Oklahoma)	Ray, N. N., & McLaughlin, J. H. (97)
Grevillea robusta	Ceylon	Small, W. (125)
	Uganda	Small, W. (122, 123)
Guizotia abyssinica	India	Sundararaman, S. (133)
Helianthus annuus	Bulgaria	Kovachevsky, I. C. (63)
		Small, W. (127)
	Palestine	Reichert, I. (100)
— *cucumerifolius*	Palestine	Reichert, I. (103)
— *tuberosus*	Palestine	Reichert, I. (103)
Hevea brasiliensis	Ceylon	Small, W. (125)
	Java	Steinmann, A. (131)
	Malaya	Weir, J. R. (159)
	Uganda	Small, W. (116)
Hibiscus sp.	Ceylon	Small, W. (117)
— *cannabinus*	India	Likhite, V. N. (69)
— *esculentus*	Cyprus	Nattrass, R. M. (87)
	Egypt	Briton-Jones, H. R. (17)
	India	Likhite, V. N. (69)
— *Rosa sinensis*	Ceylon	Small, W. (125)
— *sabdariffa*	India	Likhite, V. N. (69)

TABLE I (continued)

Host	Country	Author
Ipomoea batatas	Ceylon	Haigh, J. C. (45)
	S. Rhodesia	Tompkins, C. M., & Gardner, M. W. (141)
	Tanganyika	Wallace, G. B., & Wallace, M. M. (155)
	Uganda	Hansford, C. G. (45)
	Palestine	Reichert, I. (103)
	U.S.A. (N. Carolina)	Lehman, S. G., & Poole, R. F. (58)
	U.S.A. (California)	Tompkins, C. M. (140)
Iris sp.	Palestine	Reichert, I (103)
Jacaranda sp.	Palestine	Reichert, I. (99, 100)
Juglans sp.	Palestine	Reichert, I. (100)
— *nigra*	Palestine	Reichert, I. (99)
Juniperus sp.	Palestine	Reichert, I. (103)
	Ceylon	Small, W. (125)
Lactuca sativa	Palestine	Reichert, I. (101)
Laurus nobilis	Palestine	Reichert, I. (103)
Lavandula sp.	Italy	Goidanich, G., & Camici, L. (44)
Ligustrum sp.	Palestine	Reichert, I. (103)
Lilium sp.	Bermuda	Ogilivie, L. (88)
— *candidum*	Palestine	Reichert, I. (103)
Linum usitatissimum	India	Sundararaman, S. (133)
	S. Australia	Adam, D. B., & Stockes, J.*)
Lupinus sativus	Palestine	Reichert, I. (103)
Malus communis	Palestine	Perlberger, J. (91)
		Reichert, I. (103)
— *mitis*	Palestine	Reichert, I. (103)
Mamillaria sp.	Palestine	Reichert, I. (103)
Matthiola sp.	Palestine	Reichert, I. (103)
Medicago sativa	Australia	Carne, N. M. (26)
	New S. Wales	Anon. (3)
	U.S.A. (south)	Hoffmaster, D. E. et al. (53)
	Palestine	Reichert, I. (103)
Melaleuca armillaris	Palestine	Reichert, I. (103)
Melilotus sp.	U.S.A. (Iowa)	Young, P. A. (165)
Mentha piperita	Palestine	Reichert, I. (103).
Mucona sp.	Sudan	Andrews, F. W., & Clouston, T. W. (8)
Musa sp.	Ceylon	Haigh, J. C. (45)
	India	Uppal, B. N. (143)
	Palestine	Reichert, I. (103)
	S. Rhodesia	Wickens, G. M. (163)

*) Ref. Rev. Appl. Myc. 22:310, 1943.

Table I (continued)

Host	Country	Author
Musa paradisiaca	Ceylon	Small, W. (125)
Myrtus communis	Palestine	Reichert, I. (99, 100)
Nemesia sp.	Palestine	Reichert, I. (103)
Nicotiana tabacum	Ceylon	Small, W. (126)
	India	Likhite, V. N. (69)
	Palestine	Reichert, I. (98, 99, 100)
		Reichert, I., & Hellinger, E. (105)
	Rhodesia	Snowden, J. D. (130)
	Turkey	Bremer, H. (15)
	U.S.A. (Kentucky)	Valleau, W. D. (145)
	U.S.A. (Maryland)	Matthews, E. D., et al. (76)
Ochroma lagopus	Ceylon	Small, W. (125)
Olea europaea	Palestine	Reichert, I. (103)
Onobrychis sativa	Palestine	Reichert, I. (103)
Panicum maximum	Ceylon	Briton-Jones, H. R. (18)
Parthenum argentatum	U.S.A. (Texas)	Presley, I. T. (95)
Parinarium nobola	Nyassaland	Leach, R. (66)
Pelargonium sp.	Palestine	Reichert, I. (103)
Persea (americana?) (Avocado)	Ceylon	Small, W. (127)
— *gratissima*	Palestine	Reichert, I. (103)
Phacelia tanacetifolia	Palestine	Reichert, I. (103)
Phaseolus lunatus	Bermuda	Ogilvie, L. (88)
	U.S.A. (Carolina)	Moore, W. D. (86)
— *lunatus var. sieva*	U.S.A. (California)	Mackie, W. W. (77)
	U.S.A. (Georgia)	Andrus, C. F. (9)
— *multiflorus*	U.S.A. (California)	Mackie, W. W. (72)
— *mungo var. radiatus*	India	McRae, W. (81)
— *vulgaris*	Australia	Carne, W. N. (26)
	Brazil	Viegas, A. P. (151)
	Bulgaria	Kovachevsky, I. C. (63)
	Canada	Miller, J. J., et al. (84)
	Ceylon	Small, W. (125)
	Cyprus	Nattrass, R. (87)
	Egypt	Briton-Jones, H. R. (17)
	Greece	Sarejanni, I. A., & Cortzas, C. B. (106)
	India	Sunderaraman, S. (134)
	Italy	Goidanich, G., & Camici, L. (44)
	Palestine	Reichert, I., & Hellinger, E. (105)
	Sierra Leone	Deighton, F. C. (38)

TABLE I (continued)

Host	Country	Author
Phaseolus vulgaris (continued)	Tanganyika	Wallace, C. B. (153)
	Tunis	Maublanc, A. (77)
	Uganda	Small, W. (120)
	U.S.A. (Georgia)	Boyd, O. C. (14)
	U.S.A. (S. Carolina, Mississippi)	Haskell, R. J., & Wodd, J. I. (49)
	U.S.A. (California)	Tompkins, C. M., & Gardner, M. W. (141)
	U.S.A. (south)	Hoffmaster, D. E., et al. (53)
	U.S.S.R. (Georgia)	Kantshaveli, L. (60)
Phoenix canariensis	Malay	Sharples, A. (111)
— *dactylifera*	Palestine	Reichert, I. (103)
Physalis Alkekengi	Palestine	Reichert, I. (103)
— *peruviana*	Australia	Carne, W. M. (26)
Picea excelsa (*abies*)	U.S.A. (Pennsylvania)	Davies, S. H. (34)
Pimpinella anisum	Turkey	Bremer, H. (15)
Pinus contorta	Palestine	Reichert, I. (100)
— *halepensis*	Palestine	Reichert, I. (99, 100)
— *maritima*	Palestine	Reichert, I. (103)
Piper Betle	India	Dastur, J. F. (31)
Pisum arvense	Uganda	Small, W. (125)
— *sativum*	New S. Wales	Anon. (6)
Pithecolobium saman	Uganda	Small, W. (120)
Pittosporum tobira	Palestine	Reichert, I. (103)
— *undulatum*	Palestine	Reichert, I. (103)
Poinciana regia	Palestine	Reichert, I. (103)
Populus sp.	Palestine	Reichert, I. (103)
Prunus Amygdalus *v. amara*	Palestine	Perlberger, J. (91), Reichert, I. (103)
— *armeniaca*	Palestine	Perlberger, J. (91), Reichert, I. (103)
— *avium*	Palestine	Reichert, I. (103)
— *divaricata* (Myrobalan)	Palestine	Perlberger, J. (91), Reichert, I. (99, 100)
— *domestica*	Palestine	Reichert, I. (103)
— *Mahaleb*	Palestine	Reichert, I. (103)
— *persica*	Palestine	Reichert, I. (99, 100)
Pyrethrum cinerariifolium	Palestine	Reichert, I. (103)
Pyrus communis	Palestine	Perlberger, J. (91), Reichert, I. (103)
— *Malus*	Palestine	Reichert, I. (103)
Raphanus sativus	Palestine	Reichert, I. (103)
Rheum undulatum	Palestine	Reichert, I. (103)
Ribes sp.	Cyprus	Nattrass, R. M. (87)

Table I (continued)

Host	Country	Author
Ricinus communis	India	Likhite, V. N. (69)
	Palestine	Reichert, I. (103)
Rosa sp.	Ceylon	Small, W. (125)
	Palestine	Reichert, I. (103)
Rosmarinus sp.	Palestine	Reichert, I. (103)
Rumex sp.	Palestine	Reichert, I. (103)
Russelia juncea	Palestine	Reichert, I. (103)
Saccharum officinarum	India	McRae, W. (83)
	U.S.A.	Tervet, I. M. (137)
Santalum album	Ceylon	Small, W. (126)
Santolina sp.	Palestine	Reichert, I. (103)
Scabiosa sp.	Palestine	Reichert, I. (103)
Sesamum indicum	Burma	Small, W. (123)
	Ceylon	Briton-Jones, H. R. (18)
	Cyprus	Nattrass, R. M. (87)
	Formosa	Sawada, K. (109)
	Greece	Sarejanni, J. A., & Cortzas, G. B. (106)
	India	Likhite, V. N. (69)
	Palestine	Reichert, I. (98, 99)
	Philippines	Petrak, F. (92)
	Turkey	Bremer, H. (15)
	Uganda	Small, W. (125), Snowden, T. D. (130)
Sesbania punctata	Uganda	Small, W. (125)
Solanum Lycopersicum	Ceylon	Small, W. (125, 111)
	Cyprus	Nattrass, R. M. (87)
	Gambia	Brooks, A. J. (23)
	India	Likhite, V. N. (69)
	Palestine	Reichert, I. (99)
		Reichert, I., & Hellinger, E. (105)
	U.S.A. (Texas)	Young, P. A. (165)
— *melongena*	Ceylon	Briton-Jones, H. R. (18)
	Cyprus	Nattrass, R. M. (87)
	Greece	Sarejanni, J. A., & Cortzas, G. B. (106)
	India	Likhite, V. N. (69)
	Palestine	Reichert, I. (100)
		Reichert, I., & Hellinger, E. (105)
— *tuberosum*	Cyprus	Nattrass, R. M. (87)
	India	Dastur, J. F. (30)
	Palestine	Littauer, F. (71), Reichert, I. (99)
		Reichert, I., & Hellinger, E. (105)

TABLE I (continued)

Host	Country	Author
Solanum tuberosum (continued)	Tasmania	White, N. H. (161)
	Turkey	Bremer, H. (15)
	U.S.A. (Georgia)	Boyd, O. C. (14)
	U.S.A. (Illinois)	Boewe, G. H. (12)
	U.S.A. (southern states)	Hoffmaster, D. E. et al. (53)
	U.S.A. (Texas)	Young, P. A. (165)
Sorghum annuum	India	Uppal, B. N., et al. (144)
	Italy	Goidanich, G. ((42)
	U.S.A. (south)	Hoffmaster, D. E., et al. (53)
	U.S.A. (Texas)	Young, P. A. (165)
Stizolobium deeringianum	U.S.A. (Iowa)	Young, P. A. (165)
Styrax sp.	Palestine	Reichert, I. (103)
Tagetes erecta	Sierra Leone	Deighton, F. C. (39)
Tephrosia candida	Ceylon	Small, W. (116, 125)
Thea sp.	Ceylon	Small, W. (122, 125)
	India	Tunstall, A. C. (142)
	Java	Steinmann, A. (131)
	Nyassaland	Butler, E. J. (25)
	Sumatra	Steinmann, A. (131)
	Tanganyika	Wallace, G. B. (152)
	Uganda	Small, W. (125)
Theobroma cacao	Ceylon	Small, W. (125)
	Uganda	Small, W. (125)
Thuja sp.	Palestine	Reichert, I. (99, 100)
Trifolium sp.	Palestine	Reichert, I. (103)
	U.S.A. (Kentucky)	Hanson, L., & Valleau, W. (50)
	U.S.A. (Pennsylvania)	Chilton, S. J. P. (27)
Tristana conferta	Ceylon	Small, W. (125, 118)
Triticum sp.	Palestine	Reichert, I. (103)
Verbascum sp.	Palestine	Reichert, I. (103)
Vicia Faba	Italy	Goidanich, G., & Camici, L. (43)
— *sativa*	Bulgaria	Kovachevsky, J. C. (63)
	Uganda	Small, W. (125)
Vigna sinensis	Cyprus	Tompkins, G. M., & Gardner, M. W. (141)
	Egypt	Briton-Jones, H. R. (17)
	India	Khan, A., & Bhatnagar, N. P. (62)
	Palestine	Reichert, I. (103)
	Sierra Leone	Deighton, F. C. (38)

Table I (continued)

Host	Country	Author
Vigna sinensis (continued)	U.S.A. (south)	Hoffmaster, D. E., et al. (43)
	U.S.A. (California, Virginia)	Mackie, W. W. (72)
	U.S.A. (Iowa, Texas)	Young, P. A. (165)
Viola odorata	India	McRae, W. (82)
Vitis vinifera	Palestine	Reichert, I. (99, 100)
Zea mays	Argentine	Marchionatto, J. B. (73)
	Morocco	Maresquelle, M. (74), Reichert, I. (101)
	Palestine	Reichert, I. (100)
	Rumania	Savulescu, T., & Rayss, T. (107)
	U.S.A. (Carolina)	Mackie, W. W. (72)
	U.S.A. (Iowa)	Semeniuk, G. (170)
	U.S.A. (south)	Hoffmaster, D. E. et al. (53)
	U.S.A. (Texas)	Young, P. A. (165)
Zinnia elegans	Sierra Leone	Deighton, F. C. (39)

The host range of *S. bataticola* is seen to be extremely wide including annuals as well as woody plants such as *Citrus, Coffea, Eucalyptus, etc.* But the infection experiments carried out on various hosts with isolates from the same hosts have succeeded only in isolated cases, as on beans by Briton-Jones (17), Small (115, 125), Reichert and Hellinger (105), Kendrick (61), and Andrus (9); on cowpea by Shaw (112), and Briton-Jones (17); on *Hibiscus esculentus* by Briton-Jones (17); on *Corchorus* and *Arachis* by Shaw (112); on cotton by Shaw (112) and Vasudeva (147); on tobacco by Matthews et al. (76), and on *Sorghum* by Uppal et al. (144).

Butler (24), and later Briton-Jones (17), already observed that "infection depends on certain conditions", i.e. on a stage of weakening of the host, as Hoffmaster et al. (53) termed it, the "stage of devitalization". This has been confirmed by various investigators. Thus, Briton-Jones (22) ascribed *Sclerotium bataticola* infection to soil dryness; Dastur (29) and Hopkins (56) to poor drainage; Littauer (71) and Perlberger (91) to excessively high soil temperatures; West and Stuckey (160) and Leach (66) to low carbohydrate content of the host; Vasudeva (150) to untimely sowing and Hoffmaster & al. (53) to a weakening due to prior infection by other organisms.

Apart from the adverse environmental conditions weakening the host plants, the factors favouring the development of the fungus are high temperatures and humidities. The significance of high temperatures has been observed by many authors (9, 40, 61, 64, 71, 91,

Text-fig. 1. The world distribution of *Sclerotium bataticola*. The figures enclosed in circles indicate the number of hosts on which the fungus has been recorded in each country.

100, 104, 116, 160), and has been demonstrated experimentally by Tompkins and Gardner (141), Tompkins (140), Uppal et al. (144), Likhite and Kulkarni (70) and Vasudeva (148). They consider 30°-37°C. as the optimum temperature for the development of infection on various plants. As regards humidity, observations on the importance of a high soil moisture content for infection have been made by various authors (9, 64, 91, 104, 160), while Uppal et al. (144) and Vaseduva (148) have proved this point experimentally. Vasudeva (149) has also shown experimentally that high humidities alone do not cause infection unless coupled with high temperatures, for at high humidities and low temperatures no infection was obtained.

In the light of these ecological data concerning the development of *S. bataticola* on its host plants, the distribution of the disease over various parts of the globe, as outlined in text-fig. 1, is readily understood. It is apparent that the disease is in the main limited to tropical countries where high temperatures and high humidity prevail simultaneously. The occurrence of the disease in Mediterranean and similar climates, though by no means infrequent, may be thought to be limited to special sets of conditions where high temperature and humidity coincide, e.g. in summer crops grown under irrigation, or in crops grown in late summer and autumn when the first autumn rains may fall while temperatures are still relatively high. The latter has, for instance, been found to explain the occurrence of *S. bataticola* on groundnuts in Palestine (104). The disease may likewise develop in non-tropical regions where summer rains are accompanied by warm weather, e.g. in the south-eastern states of the U.S.A. All the more northerly occurrences of *S. bataticola,* as for instance Canada (84), must be thought to represent the result of the introduction of infection material in summer time, when high temperatures and humidities prevailed simultaneously. In such localities *S. bataticola* is unlikely to persist for any length of time and will prove serious only under exceptional conditions.

IV. MORPHOLOGICAL STUDIES

It has been mentioned in the introduction that the problem confronting us when this study was planned was the pathogenicity, both on their respective hosts and on other plants, of various strains of *S. bataticola* isolated from a number of hosts in Palestine. Some of these strains had been obtained from crop plants whole fields of which had been completely attacked, as bean, pumpkin, pepper. Besides these strains, isolates from eggplant, potato, cicer, tomato, cotton, tobacco and sesame were used for a morphological comparison. These ten isolates were kept under close observation. Macroscopic features were noted and morphological details were observed, to determine as far as possible whether the different forms obtained from the various host plants were morphologically identical or represent different strains of *Sclerotium bataticola.*

A. Methods

To obtain the fungus in pure culture, pieces of diseased material were inmersed for ten minutes in a 1% sublimate solution, then thoroughly washed under the tap to remove all traces of sublimate. Small portions were then cut off and plated out on potato dextrose agar medium in petri dishes.

Agar-film slides were used for the detailed microscopical studies of the growth and development of the isolates described below. Glass slides were aseptically covered with a fine film of nutrient agar medium, on which two sclerotia were placed well apart. Series of such slides of each isolate were prepared and placed in a closed moist sterile chamber and kept at 24° to 26°C. One glass slide of each isolate was removed daily, fixed in alcohol, cleared with lactic phenol and the preparation mounted in lactic gum arabic. Thus, one could observe more clearly and record in all detail the day by day development of the mycelium and the formation and development of the sclerotia.

B. General Description

Generally, affected plant material subcultured on nutrient agar medium showed clearly visible fungal growth within 48 hours of inoculation. By the fourth day, a somewhat fine, grayish-white mycelial growth had spread chiefly along the agar surface, accompanied by minute, blackish, more or less regular shaped sclerotial bodies, spherical or somewhat elongated in form. Subplants from young cultures, however, produced sclerotia by the second day.

Hyaline hyphae with granular contents disappearing with age, were at first produced. The developing hyphae radiated outwards along the agar surface branching freely and irregularly, chiefly towards their tips, producing prostrate and aerial growth. The aerial branches were somewhat shorter and generally inclined towards the direction of growth so that the denser peripheral growth thus gave a feathery fan-like appearance to the whole mycelium. This became more marked in certain isolates described below in which the older aerial mycelium gradually collapsed and a break-down set in from the centre outwards. Other isolates, however, produced a persistent, dense, more or less tufted aerial mycelium. Branches from the main hyphae were generally formed at right angles, but at a later stage many bent forward, tending to grow paralled to the parent hypha. Resupinate branches, i.e. bending back and growing in the opposite direction, were sometimes observed. Certain hyphal threads showed a thickening and darkening in colour. The majority of the branches showed a characteristic constriction near the base and the septum separating the lateral hypha from the parent branch was usually found at the constriction. The shorter main hyphae measured from 5 to 10.5μ and the finer ones from 2 to 3μ in width. The cells varied considerably in length, measuring from several to 46μ. Short rows of short, thick-walled, irregular or barrel-shaped cells were formed by a series of transverse divisions of certain hyphal cells. These cells, which measured from 4 to 23μ across and contained numerous oil globules, turned brown in colour.

Free branching and anastomosis of the hyphae with themselves or with neighbouring branches occurred, often marking the beginnings of a sclerotium. As the sclerotia formed in the agar medium, they appeared as minute brownish structures, blackening with age and accompanied by a slight darkening in colour of the older hyphae. By the seventh day the mycelium of most of the forms examined showed almost a complete breakdown, except, perhaps, for some relatively thick-walled, brown pigmented hyphal threads and some small fragments of hyphae still attached to the sclerotia and persisting for a considerable time. Thus the agar medium appeared darker in colour due chiefly to the innumerable minute black sclerotia dotted throughout especially on the exposed surface layer.

C. Comparative morphology of isolates from ten host plants

1. *Macroscopical*

(a) Type of growth

When repeatedly subplanted under identical conditions, the bean, pepper, tomato, eggplant, cucumber, and *Cicer* isolates, and allowing for minor differences also the pumpkin isolate, showed such a marked similarity of growth and development, that they naturally formed one group. Sesame and tobacco isolates, however, gave a type of growth distinct from this group and differing also to a slighter extent from each other. The cotton isolate resembled in certain aspects that of tobacco and in other aspects that of sesame.

Detailing the type of growth of the first group, the fungus in plate cultures showed a rather fine mycelial growth, with a very slight amount of coarse, dark hyphae, somewhat more, however, in pumpkin. Aerial growth produced towards the edge of the colony collapsed and died down within 24 to 48 hours of being produced, giving a still sparser appearance to the centre of the colony (plate I, fig. 1). Distinct from this type of mycelial growth was the growth of the sesame and to a lesser extent the tobacco isolates, which exhibited, more especially at the centre, a denser growth with a copious amount of aerial mycelium which was persistent for a considerable time (plate I, fig. 2). The cotton isolate produced less aerial growth than either that of tobacco or sesame, but appreciably more than the first group. After several days, plate cultures of the sesame, tobacco and cotton isolates, in contrast to the isolates of the bean group, showed a tendency for the formation of coarse dark fumaceous hyphae with numerous short thickened cells and relatively large irregular sclerotial masses, particularly pronounced in the tobacco isolate (plate I, figs. 3-5; plate II, figs. 6-7). But, whereas these latter characteristics were variable, the persistent, thick, dense, aerial mycelium was a constant diagnostic feature.

On the basis of the observations recorded in table II we distinguish between three main types of growth: (1) The Bean type including also tomato, egg-plant, cucumber, pumpkin, *Cicer* and pepper; (2) the Tobacco type, including also the cotton isolate; (3) the Sesame

type. All these types of growth remained constant throughout our two years' study.

TABLE II

The type and rate of mycelial growth of isolates of Sclerotium bataticola from 10 *hosts, on potato glucose agar plate cultures**)*

Source of S. bataticola isolate	*Type of growth*	*Rate of growth (in cm)*				
		first day (mean of 3 dishes)	*second day (mean of 3 dishes)*	*third day*		
				1st dish	*2nd dish*	*3rd dish*
bean	breakdown of most of the mycelium; relatively few barrel-shaped cells and fumaceous hyphae attached to sclerotia	1.6	5.5	covered	covered	covered
eggplant	similar to bean isolate	1.5	5.0	covered	7.3	8.1
potato	similar to bean isolate	1.8	5.5	covered	covered	7.7
pepper	similar to bean isolate	0.7	4.2	6.4	covered	7.0
Cicer	similar to bean isolate except more barrel-shaped cells	1.8	5.1	covered	8.6	7.0
tomato	similar to bean isolate	1.2	5.1	covered	8.3	7.9
pumpkin	slight amount of persistent fumaceous hyphae, with fairly numerous barrel-shaped cells	1.7	5.3	covered	8.0	covered
cotton	non-uniform and somewhat patchy persistent fumaceous aerial mycelium with abundant barrel-shaped cells	1.4	4.5	8.8	8.1	5.9
tobacco	as cotton, but non-uniformity and patchiness more pronounced	1.1	4.1	7.0	7.7	5.9
sesame	denser and more uniform persistent fumaceous aerial mycelium in concentric zones; abundant barrel-shaped cells	1.5	4.3	7.0	7.8	5.9

In the general distribution of the sclerotia in the culture medium, the three types could be readily distinguished. The Bean type had a more or less even distribution of its sclerotia throughout the surface layer of the medium, the sclerotia appearing distinct and separate because of the breakdown of the mycelium (plate I, fig. 3; plate II, fig. 6). The Tobacco type had a characteristic distribution of its sclerotia,

*) diameter of petri-dish — 9 cm.

especially in the tobacco isolate. Here the strands of fumaceous persistent hyphae produced small tufts of mycelium, which also turned brown and bore numerous small black sclerotia, thus giving the outstanding patchy effect in plate cultures (plate I, fig. 4). Dark strands projecting radially from the centre were sometimes observed. The Sesame isolate had a more or less uniformly dense, persistent, fumaceous aerial mycelium formed in concentric zones, obscuring somewhat the appearance of the sclerotia (plate I, fig. 5).

(b) Rate of growth

The rate of growth in plate cultures of the isolates of *S. batatícola* from the ten hosts was observed for 3-7 days. The data obtained for the first three days are presented in table II.

The figures of this table show that the isolates from cotton, sesame and tobacco resemble one another in their growth rate and differ from the remaining isolates. This distinction already became apparent on the second day when the isolates from the above three hosts averaged only 4.1-4.5 cm. growth whereas the other isolates (except that from pepper) reached 5.0-5.5 cm. On the third day all the latter isolates, now including pepper, had completely covered at least one dish and growth in the remaining dishes reached 7.0-8.6 cm. (6.4 cm. in the dish of the pepper isolate). On the other hand, not a single dish of the isolates from cotton, sesame and tobacco was completely covered and in some dishes less than 6.0 cm. growth had been made by the third day. In short, the Bean type tends to show a faster rate of growth.

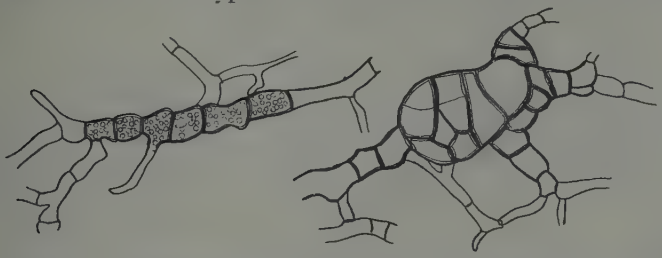
These results lend support to the opinion deduced from the macroscopical appearances of the mycelium and sclerotia that the tobacco, sesame and cotton isolates are not identical with the rest of the isolates which we have termed the Bean type.

2. Microscopical

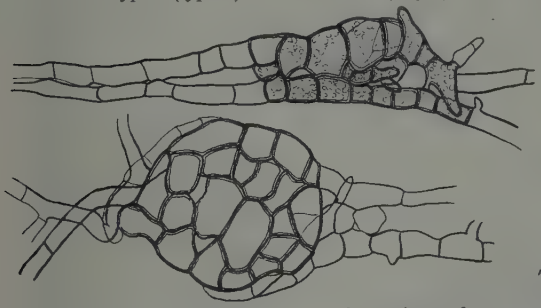
(a) Formation of sclerotia

The more frequent type of formation of the sclerotium was from a row of brownish, swollen, barrel-shaped cells often showing internal segmentation. These barrel-shaped cells generally fused with the freely anastomosing lateral outgrowths from these or adjacent cells of the same hypha or with those from barrel-shaped cells of neighbouring hyphae, forming eventually a compact pseudoparenchymatous mass which darkened with age. Often branches arose close to and growing around this sclerotium, finally becoming incorporated in it. Being younger, with more or less regular sized cells; these branches formed a smooth brownish covering to the sclerotium. When the sclerotium was formed from considerably swollen barrel-shaped cells undergoing internal segmentation, the outer layer of cells was cut off last and narrower, forming a membrane to the sclerotium. Old sclerotia appeared black, generally smooth and more or less regular, along a hyphal thread, or to one side of it, or between several hyphae.

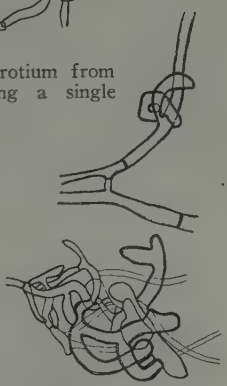
Less frequently sclerotia were seen to be formed from anastomosing cells of single normal hyphae or from two or more adjacent normal hyphae, or from the fusion between barrel-shaped cells and normal cells of other hyphae.



Text-fig. 2. Two stages in the formation of a sclerotium from the swollen, barrel-shaped cells arising along a single hypha (type I). *Cicer* isolate (x 575).



Text-fig. 3. Two stages in the formation of a sclerotium from the fusion of barrel-shaped cells of two neighbouring hyphae (type II). *Cicer* isolate (x 575).



Text-fig. 4. Two stages in the formation of a sclerotium from normal cells of a single hypha (type III). Tobacco isolate (x 575).

A certain amount of coalescence took place between two or more sclerotia placed end-wise or in close proximity, forming one large irregular sclerotium. When crushed the sclerotia broke into small carbonaceous fragments liberating a comparatively large amount of oil globules.

The close study of the origin and development of the sclerotia thus tended to show five types of formation:

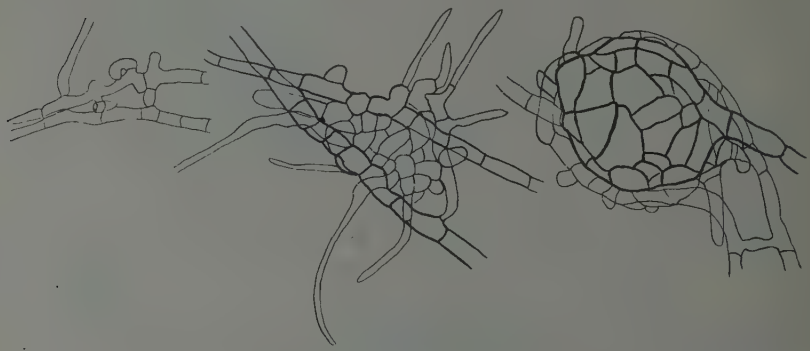
Type I — from swollen, barrel-shaped cells arising along a single hypha, often showing internal segmentation with anastomosing outgrowths from and around these swollen cells (text-fig. 2).

Type II — from the fusion between barrel-shaped cells of two neighbouring hyphae (text-fig. 3).

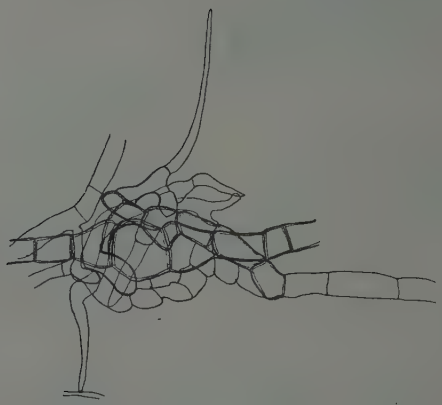
Type III — from normal cells of a single hypha (text-fig. 4).

Type IV — from the fusion of normal cells of adjacent hyphae (text-fig. 5).

Type V — from the fusion of barrel-shaped cells of one hypha, with normal cells of other hyphae (text-fig. 6).



Text-fig. 5. Three stages in the formation of a sclerotium from the fusion of normal cells of adjacent hyphae (type IV). Tobacco and pepper isolates (x 575).



Text-fig. 6. Formation of a sclerotium from the fusion of barrel-shaped cells of one hypha with normal cells of other hyphae (type V). Pepper isolate (x 575).

The types of sclerotial formation observed in each of our 10 isolates are indicated in the second column of table III. We note that type I was found in all isolates, and type II was found in most of the Bean type of isolate; but types III and IV were restricted to the Tobacco and Sesame types of isolate. Type V was found only in pepper. From this aspect, too, our isolates appear to represent at least two distinct groups: (a) our so-called Bean type which includes the isolates from bean, eggplant, potato, pepper, *Cicer*, and tomato, in which sclerotial formation always followed type I, and frequently type II, but not types III and IV; (b) represented by the cotton,

tobacco and sesame isolates in which sclerotial formation of types III and IV, besides type I, were always found, whereas instances of type II were not observed. It must be noted that the pumpkin isolate indicated a certain resemblance to the Tobacco and Sesame types in showing type III of sclerotial formation.

(b) Shape of sclerotia

The shape of sclerotia observed in our 10 isolates is indicated in column 3 of Table III. We note that all the isolates we have grouped under the Bean type possessed rounded or somewhat elongated smooth sclerotia. On the other hand the sclerotia produced by the Sesame type were chiefly irregular in shape (plate II, figs. 6 and 8).

(c) Size of sclerotia

To determine whether or not the sclerotia produced by the 10 isolates of *S. bataticola* differ in size, 50 sclerotia from each isolate were measured. Even though the number of sclerotia measured were insufficient from a biometric point of view, yet the measurements (see table III, columns 4 and 5) showed big fluctuations in length and width of the various sclerotia, and no differences between them were revealed.

TABLE III

Types of sclerotial formation, size and shape of sclerotia and special cultural features of isolates of Sclerotium bataticola from 10 hosts

Source of isolate	*Type of sclerotial formation (see pages 127-128)*	*Shape of sclerotia*	*Range of measurements (microns)*	
			length	*width*
bean	I, II	more or less rounded smooth sclerotia	61-106	57-84
eggplant	I	smooth, rounded or elongated sclerotia	57-114	47-110
potato	I, II	as bean, also many irregular sclerotia	53-117	43-90
pepper	I, II, V	as bean	50-118	50-87
Cicer	chiefly I, also II	roundish, somewhat elongated smooth sclerotia	47-98	44-86
tomato	I, II	similar to bean	53-114	49-87
pumpkin	I, II, III	rounded, smooth sclerotia	57-124	53-104
cotton	I, III, IV	sclerotia somewhat irregular in shape	57-124	49-117
tobacco	I, III, IV	rounded elongated and irregular shaped sclerotia	53-134	49-104
sesame	I, III, IV	chiefly irregular sclerotial masses, also more or less rounded sclerotia	47-151	40-124

(d) Size of mycelial parts

An attempt was also made to measure certain mycelial characteristics such as the size of the barrel-shaped cells, the constriction

at the septum, and the distance of the septum from the parent branch. The data obtained are presented in tables IV and V and show that there were no clear-cut differences between the various isolates.

TABLE IV

Size and frequency of barrel-shaped cells of the 10 *isolates of S. bataticola*

Source of isolate	*Length range (microns)*	*Width range (microns)*	*Mean length & width (microns)*	*Frequency*
bean	8-10	5-11	8×8	relatively few
eggplant	6-11	8-13	8×10	as bean
potato	5-13	7-10	8×7	as bean
pepper	8-19	8-23	10×13	as bean
Cicer	7-14	8-16	10×12	fairly numerous
tomato	7-13	7-13	9×8	as bean
pumpkin	8-12	7-19	9×12	fairly numerous
cotton	7-20	8-21	11×11	numerous
tobaco	8-15	8-23	10×11	numerous
sesame	6-13	6-13	10×10	numerous

TABLE V

Width of constriction at septum and distance of septum from parent branch in the 10 *isolates of S. bataticola*

Source of isolate	*Width of constriction at septum range (microns)*	*mean (microns)*	*Distance of septum from parent branch (microns)*
bean	0 —0.48	0.26	0.5—3.0; majority 1—2
potato	0.2—0.64	0.41	1—2; one measured 6
pepper	0 —0.50	0.26	1—22; majority 1—2, several measured 3—4, one 15, and another 22
Cicer	0 —0.56	0.28	0.5—2; one measured 4, another 7
tomato	0 —0.64	0.37	0.5—3; one measured 9
tobacco	0 —0.63	0.36	1—5; majority 1—2, small number measured 3—5
sesame	0 —0.50	0.30	0.5—6; majority 1—3

V. CHROMOGENESIS

When the fungal isolates were grown on potato wedges held above water in special test-tubes, a distinct coloration of the aqueous solution took place, the colours varying among the different isolates. Further sets of four potato wedges for each fungal strain were inoculated on three separate occasions to determine whether the pigmentation of the aqueous solution in each tube was constant for each strain. The observations are given in Table VI.

TABLE VI.

Pigmentation of aqueous solution by isolates of S. bataticola

Source of isolate	*1st series*	*2nd series*	*3rd series*
bean	2 faintly pink 2 yellow-pink	yellowish-brown	pink
pumpkin	faintly pink	3 pink 1 yellowish	pink
pepper	pink	2 yellowish 2 pinkish	pink
Cicer	yellow	yellow	yellow
eggplant	2 pinkish 2 yellow-pink	yellowish-brown	faintly yellow
tomato	red	pink	red
potato	yellow	pink	3 pink 1 faintly discoloured
cotton	pink	yellow	yellow-pink
tobacco	red	reddish-brown	reddish-brown
sesame	deep-yellow	deep yellow	deep yellow

Although some strains showed variation in pigmentation yet the results tend to suggest certain physiological differences between a number of the isolates. Only four isolates exhibited uniform chromogenetic properties in all three series: the *Cicer* isolate always gave a yellow, the tomato isolate a red-pink, the tobacco isolate a red to reddish-brown, and the sesame isolate a deep yellow pigmentation. In this respect, again, the sesame isolate differed clearly from the bean and from most of the other isolates which, we have already observed, resemble the latter in many of their characteristics.

VI. INOCULATION EXPERIMENTS

Soil inoculation experiments were carried out to ascertain the pathogenicity of the isolates on certain of the host plants.

A. Methods

The ten isolates were grown on sterilised potato wedges in test tubes, and within a week the fungus had in each case formed a black crust over the potato with a varying amount of aerial mycelium.

160 numbered earthenware pots were sterilised by dipping for several minutes in a 4% formalin solution, then filled with sand and finally thoroughly wetted with a 0.2% formalin solution. All pots were covered with sacks that had been sterilised for at least an hour with 0.2% formalin solution and left overnight. For a period of a week the soil was turned over daily with a sterilised rod to enable all traces of formalin to disappear. A number of seeds of egg-plant, tomato, pumpkin, *Cicer* and bean were disinfected for twenty minutes in a formalin solution (1 cc formaldehyde in 320 cc water) then well washed in water, dried and left for 24 hours to complete the drying. The pots were then arranged in sets of forty, and each set sown with one type of disinfected seeds. Ten pots from each set were left as controls while the remaining thirty were

inoculated in sets of three with a piece of potato culture of each of the isolates, respectively, placed in direct contact with the seeds. The pots were covered and kept in the laboratory for several days (temperature 18.5°—23°C), and watered every other day with 25 cc water. The pots were removed to the open as soon as the seedlings began to appear, and watered daily according to their requirements. The daily mean minimum temperature was 15.7°C, and the mean maximum 32.8°C.

B. Results

Table VII gives the final results of these inoculation experiments.

a b

Text-fig. 7. Pot inoculations of beans with two isolates of *Sclerotium bataticola*. Each picture shows three inoculated pots and one control pot (on the right).

(a) Inoculation with the sesame isolate, failing to infect the beans.
(b) Inoculation with the bean isolate, resulting in virulent infection.

Except for a few doubtful cases, from which the fungus inoculated was not recovered, the 10 isolates failed to infect eggplant, tomato, pumpkin and *Cicer*. Only bean proved to be susceptible to infection by all isolates except that from sesame. According to their virulence on bean the isolates may be divided into 4 groups:

I Non-virulent, i.e. neither pre- nor post-emergence infection: sesame isolate (text-fig. 7a).

II Mildly virulent, i.e. no pre-emergence infection but 10-20% post-emergence losses: tomato, *Cicer* and pepper isolates.

III Markedly virulent, i.e. little pre-emergence losses, but 50-80% post-emergences losses: eggplant, tobacco, potato, and cotton isolates.

IV Strongly virulent, i.e. 20-50% pre-emergence losses, all plants that emerge subsequently attacked: bean and pumpkin isolates (text-fig. 7b).

S. bataticola was in every case re-isolated from the infected bean plants.

TABLE VII

The percentages of healthy and diseased seedlings from seeds inoculated with Sclerotium bataticola from various sources

Host: / Source of inoculum	*Eggplant**)*		*Tomato**)*		*Pumpkin***)		*Cicer***)		*Bean***)	
	healthy %	*infected* %	*healthy* %	*infected* %	*healthy* %	*infected* %	*healthy* %	*infected* %	*healthy* %	*infected* %
Control, non-inoculated	56	0	74	0	90	0	92	0	94	0
bean	50	0	87	3?	73	0	87	0	0	53
eggplant	47	7?	70	0	100	0	80	0	33	47
potato	73	0	67	10?	73	0	93	0	20	80
pepper	47	0	70	0	53	0	40	0	73	20
Cicer	50	0	87	0	80	0	93	0	80	13
tomato	53	0	80	3?	90	0	80	0	80	7
pumpkin	47	3?	80	0	90	0	73	0	0	67
cotton	53	0	63	3?	90	0	100	0	7	80
tobacco	80	0	100	0	90	0	93	0	33	60
sesame	40	0	77	0	80	0	60	0	100	0

*) 3 pots with 10 seeds per pot served for each inoculation series, and 10 pots with 10 seeds per pot for control.

**) 3 pots with 5 seeds per pot served for each inoculation series, and 10 pots with 5 seeds per pot for control.

A description of the symptoms observed on beans may be of interest. The first signs of disease were noted by the third day after appearance of the seedlings. Black spots appeared on a number of the epigeal cotyledons, and in several cases blackish scars were seen on the hypocotyl above soil-level. These spots developed until the cotyledons became entirely black, and in severe cases the plumule became attacked and was arrested in growth so that the plant rotted in its early stages of development. In less severe cases the plumule developed, but gave rise to a stunted growth with small mosaic or mottled leaves, due to a yellowing of the softer leaf tissue while the veins remained green. Besides the mottled effect a number of leaves became irregular and wrinkled. Some of the inoculated plants grew tall and appeared more or less healthy except for a slight mottling of some of the leaves.

VII. DISCUSSION

A. Formation of sclerotia

The first to make observations on the sclerotial formation of *Sclerotium bataticola* was Taubenhaus in 1913 (135) who gave a very brief description of the fungus accompanied by a series of drawings. These drawings tend to show sclerotial formation from one or several hyphae which do not appear to produce typical swollen, barrel-shaped cells. These may perhaps refer to our types III and IV.

Butler in 1918 (24) was actually the first investigator to describe in some detail the development of the sclerotia. On p. 12 of his book Butler describes the formation of sclerotia as follows:

"In the development of the sclerotia two types may be distinguished. In the one the whole body is the product of a single hypha. This becomes segmented into short cells and gives out lateral branches, which segment in their turn. The branches grow parallel with and adhere to the sides of the parent hypha, and by the constant repetition of this process a mass of solid fungus tissue results... In the other type a number of distant hyphae take part in the formation of the sclerotium, all branching freely and giving off a mass of intertwined filaments, which by repeated segmentation and lateral fusion may lose all trace of this filamentous structure..."

Elsewhere in this book (p. 283), when discussing the occurrence of the disease on cowpeas, Butler again deals with the formation of sclerotia and states:

"The sclerotia are formed from a single hypha in which a large number of transverse divisions take place, so that a row of short barrel-shaped cells is produced... Some of these give rise to lateral outgrowths consisting of one or two cells, which grow parallel with, and adhere to, the side of the parent hypha..."

Butler's first type of sclerotial formation corresponds to our type I, while his second type is identical with our type IV.

BRITON-JONES (17) who studied the sclerotial development of the fungus on cotton described the formation of sclerotia as follows:

"As already stated, the first step towards the formation of a sclerotium is the division of a hypha into short, barrel-shaped cells. The short cells then give rise to branches which may either grow outwards and become branched, the branches anastomosing with neighbouring branches from other similar cells, or else they develop at first into short barrel-shaped cells which remain closely adhering to the sides of the parent hypha and later themselves give rise to branches".

BRITON-JONES evidently had before him sclerotial forms comparable with our types I and II.

The next to deal with the formation of sclerotia in *S. bataticola* was HOPKINS (58). This author studied the features distinguishing this species from *S. lamellifera* which has long been confused with the former. His description and accompanying figures do not give a sufficient picture of the actual formation of the sclerotia. The description somewhat suggests a resemblance to our type I, but this is not borne out by the figures.

The formation of sclerotia by *S. bataticola* has also been studied by UPPAL, KOLHATKAR and PATEL (144), who made the following statement:

"They (the sclerotia) are formed from a hypha the cells of which repeatedly divide, giving rise to masses of irregular and barrel-shaped cells. Secondary branches arise and curl round one another so that a minute sclerotium is formed."

This description, which again fails to add anything to BUTLER's, may be considered to refer to BUTLER's first type, i.e. our type I. No other modes of sclerotial formation are mentioned by these authors.

The above quotations are all we could find concerning sclerotial formation by *S. bataticola* in the literature available to us. In short, we note that our type I (text-fig. 2) was observed by BUTLER, BRITON-JONES, and UPPAL et al.; our types III and IV (text-figs. 4-5) are perhaps to be compared with TAUBENHAUS' drawings. Our type IV, however, was also given by BUTLER, whereas our type V (text-fig. 6) has not been noticed by any other investigators.

B. Strains

1. *Mycelial and sclerotial growth*

As mentioned above, considerable differences in growth characteristics were apparent between some of our isolates. No mention of such differences in cultures isolated from various hosts is made in the older literature, but they have variously been noted in more recent work. Thus TOMPKINS and GARDNER (141) present figures showing considerable divergence in the mycelial growth of isolates from five hosts. But they do not attempt to explain this phenomenon and merely

state that "no two of the cultures were alike in cultural characters". Miller et al. (84), too, stress the variability in cultural characters of their isolates from diseased bean plants. In this connection we note that our isolates showed to a marked degree constancy of cultural features in repeated subplants over an extended period. Henson and Valleau (50) have observed and photographed two types of mycelial growth of isolates of *Sclerotium bataticola* from clover. The authors characterise the two growth habits as "a sparse, resupinate, fan-like growth" and "an abundant aerial weft". The former could well be our Bean type even though we would not define the mycelial growth as typically resupinate. But the second type of growth is insufficiently described and the authors' photograph bears a certain resemblance with our Tobacco type.

Our morphological studies have shown that in respect of the type and rate of mycelial growth and of the type of sclerotial formation the isolates dealt with in this work fall into three distinct groups: The one which we have referred to as the "Bean type" produces a fine mycelial growth developing relatively rapidly, with a comparatively small amount of barrel-shaped cells and sclerotia formed mostly either by the fusion of anastomosing outgrowths from and around such swollen cells or by fusion of barrel-shaped cells from two neighbouring hyphae. The sesame, tobacco, and cotton isolates had in common a coarser and slower growth with persistent fumaceous aerial mycelium, bearing a great amount of barrel-shaped cells and sclerotia formed either from the barrel-shaped cells of a single hypha or by the fusion of normal cells from one or more hyphae. But the tobacco and cotton isolates differed from sesame in that the latter showed a uniform type of aerial growth in concentric zones whereas tobacco and cotton showed a non-uniform and more or less patchy type of aerial growth. Thus, we are justified in dividing these three isolates into two further types: the "Tobacco type" including the cotton isolate, and the "Sesame type".

2. *Pathogenicity*

It is interesting and significant that in attempts to establish the pathogenicity of *S. bataticola* on herbaceous plants inoculations have rarely succeeded except with beans and some other plants as mentioned above (p. 120). Success was more readily attained by inoculations of fleshy parts of plants and of fruits, e.g. on chilli, sweet potato, tomato, apple, cucumber, turnip, and beet (75, 115, 135, 141). On woody plants, on the other hand, inoculation with *S. bataticola* has failed (125).

In our inoculation experiments on eggplant, tomato, pumpkin, *Cicer* and bean, only beans were affected by the isolates from all other hosts with the exception of the sesame isolate. We note that in this respect, too, the latter isolate differed fundamentally from the isolates previously referred to as members of the "Bean type"; whereas the cotton and tobacco isolates, though differing from the Bean type in

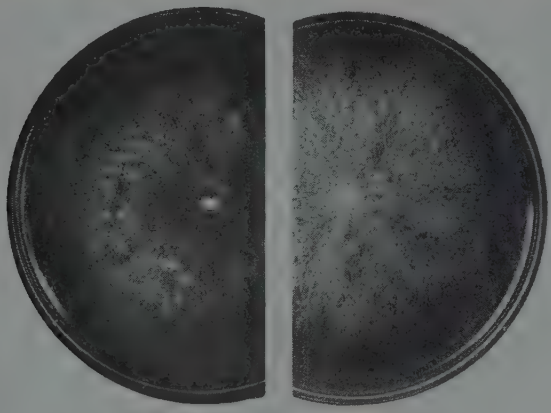


Fig. 1

Fig. 2

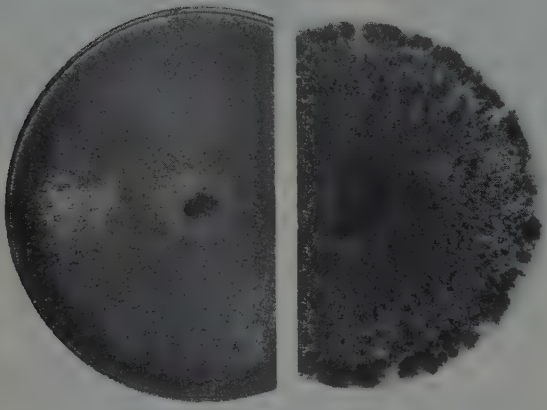


Fig. 3

Fig. 4

Fig. 5

REICHERT & HELLINGER – *SCLEROTIUM BATATICOLA*

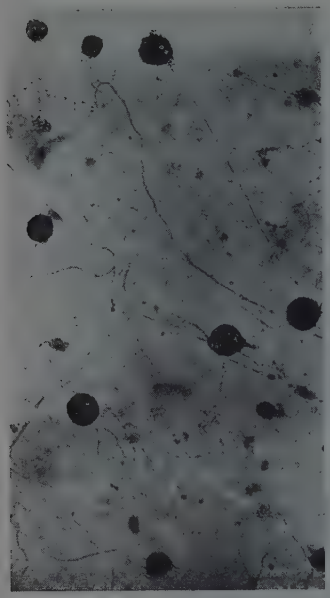


Fig. 6

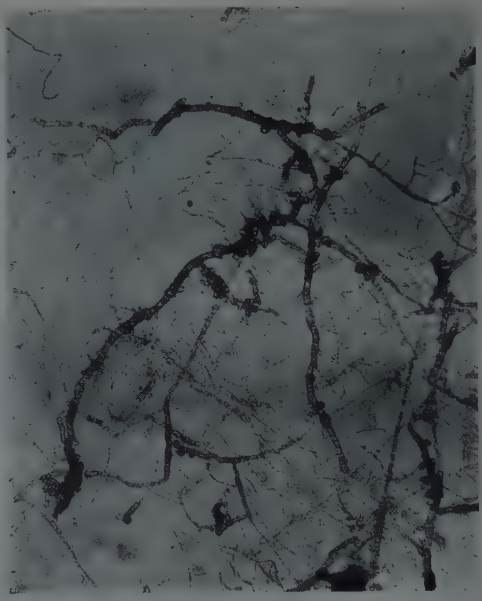


Fig. 7

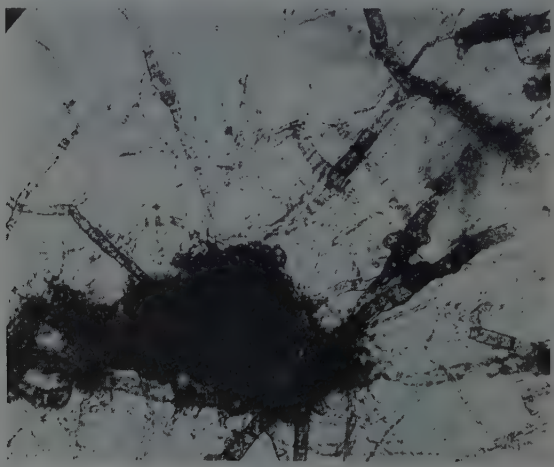


Fig. 8

cultural and morphological characters, resembled it in their pathogenicity to the hosts tested.

3. *Chromogenesis*

Chromogenetic changes in the substrate were observed to be induced by *S. bataticola* as far back as 1925 by SMALL (120), who stated that "certain strains consistently caused a prune agar medium to become black, while others left it transparent". According to an abstract of a paper by HAIGH (45), he made observations on chromogenesis of the fungus, but unfortunately his paper was unavailable to us. TOMPKINS and GARDNER (141) reported that on Brown's asparagin agar one strain of the fungus produced a brown colour, while others produced a pinkish one. Our observations are an attempt at a systematic comparison of the chromogenetic properties of various isolates. As mentioned above, some pronounced differences between the isolates were apparent, but the question requires additional study.

4. *Sub-division of the species S. bataticola*

Reviewing the species *S. bataticola* in the light of our above study we arrive at the following conclusions :-

Physiologically, the sesame isolate differs from all the others, except *Cicer* with which it showed a certain resemblance, by the production of a deep yellow colour in the aqueous portion of a potato wedge culture. With regard to pathogenicity, again, the sesame isolate stands apart as the only one that failed to infect beans. These physiological differences in conjunction with the morphological and cultural differences revealed in our ten isolates warrant their grouping into three types :-

(1) The Bean type, comprising the isolates from bean, tomato, pepper, potato, eggplant, *Cicer,* and pumpkin.

(2) The Sesame type.

(3) The Tobacco type, comprising isolates from tobacco and cotton, which is intermediate between (1) and (2). Although they resemble the latter morphologically, yet they differ from it in certain growth characters and, unlike sesame, are pathogenic to beans.

We accordingly propose to divide the species *S. bataticola* into the following three subspecies :-

1. Sclerotium bataticola ssp. typica

Characterised in culture by a quick growth of fine, non-persistent mycelium, and a more or less even distribution of smooth, round sclerotia. Relatively scarce production of barrel-shaped cells, and fumaceous hyphae. Pathogenic to bean.

This subgroup comprises our isolates from bean, eggplant, pumpkin, potato, pepper, *Cicer,* and tomato.

2. Sclerotium bataticola ssp. sesamica

Characterised in culture by a pronounced dense, uniform, persistent, fumaceous aerial mycelium in concentric zones, and with abundant barrel-shaped cells. Mycelial growth is relatively slow and the sclerotia are irregularly distributed. Non-pathogenic to bean.

This subspecies corresponds solely with the fungus we isolated from sesame.

3. Sclerotium bataticola ssp. intermedia

Characterised in culture by a pronounced non-uniform, more or less patchy, persistent, fumaceous aerial mycelium. Mycelial growth is relatively slow and sclerotia are irregularly distributed. Pathogenic to bean.

This subspecies comprises our isolates from cotton and tobacco.

VIII. SUMMARY

1. The nomenclature of *Sclerotium bataticola* is reviewed and discussed. It is advised that the use of the name *Rhizoctonia bataticola* should be discontinued; that the name *Macrophomina phaseoli* should solely be applied to strains forming pycnidia only, whereas the name *S. bataticola* be given to those strains forming only sclerotia, while strains forming both pycnidia and sclerotia should be referred to as *Macrophomina* (*Sclerotium*) *phaseoli*.

2. The host and distribution range of *S. bataticola* is fully tabulated. 118 host plants have been recorded for Palestine and 132 host plants for other countries. The distribution of the disease indicates its dependence on ecological factors, chiefly high temperature and humidity.

3. A general description is given of the development of the mycelium and sclerotia of *S. bataticola* on potato-glucose-agar.

4. A comparative study of the morphology of isolates from ten host plants, namely, bean, eggplant, potato, pepper, *Cicer*, tomato, pumpkin, cotton, tobacco, and sesame, has shown marked differences in the type and rate of their growth in culture. Sesame, tobacco and cotton isolates produced coarse, persistent, aerial mycelium with abundant barrel-shaped cells, dense and more or less uniformly distributed in the sesame isolate in concentric zones, but irregularly produced in patches in cotton and tobacco isolates. The rest of the isolates, except that from pumpkin, produced a fine collapsible mycelium with a very slight production of fumaceous hyphae and barrel-shaped cells. The pumpkin isolate, although resembling in general the latter group showed, however, relatively more hyphae and barrel-shaped cells.

5. Five distinct types of sclerotial formation have been observed: sclerotia arising from barrel shaped cells either along a single hypha (Type I) or from two adjacent hyphae (Type II); or arising from normal cells of a single hypha (Type III) or from two adjacent

hyphae (Type IV); or arising from barrel shaped cells of one hypha fusing with normal cells of a second hypha (Type V).

Type I was found in all isolates; Type II in bean, potato, pepper, *Cicer*, tomato and pumpkin; Types III and IV in cotton, tobacco, and sesame, whereas Type V was found only in pepper.

6. The ten isolates did not differ markedly in the size of their sclerotia nor in their mycelial parts, but some differences were apparent in the shape of the sclerotia, which were roundish and smooth in bean, eggplant, potato, pepper, *Cicer*, tomato, pumpkin isolates; and more or less irregular in cotton, tobacco and sesame isolates.

7. A comparison of a chromogenetic character of the ten isolates on aqueous potato extract from potato wedges, though not wholly conclusive, showed that the isolate from sesame produced a deep yellow colour distinct from the colour produced by the other isolates, with perhaps the exception of that from *Cicer* which produced less intense yellow colour.

8. The pathogenicity of the ten isolates was tested on eggplant, tomato, pumpkin, *Cicer* and bean plants. All the isolates except that from sesame attacked the bean, whereas eggplant, tomato, pumpkin and *Cicer* were not infected.

9. According to the morphological, cultural and pathogenic differences revealed in the ten isolates of *S. bataticola* the species has been divided into three subspecies (1) ssp. *typica* comprising isolates from bean, tomato, pepper, potato, eggplant, pumpkin and *Cicer;* (2) ssp. *sesamica* represented by the sesame isolate alone; and (3) ssp. *intermedia* comprising the tobacco and cotton isolates.

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EXPLANATION OF PLATES

Plate I

Growth in culture of various isolates of *Sclerotium bataticola.*

Fig. 1. Bean isolate, after 48 hours; fine mycelial growth, with very slight amount of coarse, dark hyphae; the aerial growth at the edge of the colony has collapsed.

Fig. 2. Tobacco isolate, after 48 hours; denser growth with copious amount of aerial mycelium.

Fig. 3. Bean isolate, after 6 days; sclerotia are evenly distributed and appear distinct and separate because of the breakdown of the mycelium.

Fig. 4. Tobacco isolate, after 6 days; small tufts of brown mycelium bear numerous small, black sclerotia giving the culture a patchy appearance.

Fig. 5. Sesame isolate, after 6 days; dense, persistent, fumaceous aerial mycelium somewhat obscures the appearance of the sclerotia.

Plate II

Fig. 6. Bean isolate, showing a fine mycelium and roundish sclerotia (x 55).

Fig. 7. Sesame isolate, showing coarse, dark hyphae with numerous short, thickened cells (x 55).

Fig. 8. Sesame isolate, showing irregular shaped sclerotium (x 150).

PHYTOPHTHORA HIBERNALIS *)

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Brown rot of citrus fruits and gummosis of the stem of citrus trees in Palestine were found in 1931 by *Reichert* and *Littauer* (9) to be due to *Phytophthora citrophthora* and *P. parasitica.*

In January 1945, an additional species of *Phytophthora* of lemon fruits was isolated by the author, and was suspected to be *Phytophthora hibernalis.* In 1947, this fungus was also isolated from Shamouti orange fruits.

P. hibernalis was first found in 1925 by CARNE (2) in Australia and by MONIZ DA MAIA (7) in Portugal. According to TUCKER (11) and PETRI (8), *P. hibernalis* Carne is identical with *P. syringae* Klebahn. However, LEONIAN (6) maintains *P. hibernalis* distinct from *P. syringae.* As a means of differentiation of these two species he stated that *P. hibernalis* forms its sexual bodies abundantly when transferred from pea-broth to distilled water, while *P. syringae* fails to form such bodies under these conditions. Nevertheless, LEONIAN (6) mentions that *P. hibernalis, P. syringae* and *P. porri* are very similar, both morphologically, and physiologically, and he adds that it is probable that sooner or later these three species will be merged into one.

In order to study the identity and characteristics of this fungus, studies were made of:

1) The morphology of the fungus.
2) The influence of temperature on the development of the fungus.
3) The influence of the different culture media on the development of the fungus and on the production of its fructifications.
4) The pathogenicity of the fungus in relation to different citrus fruits.
5) The pathogenicity of the fungus in relation to different host-plants for differential diagnosis.
6) The application of tests of differential growth for differential diagnosis.

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I. MORPHOLOGICAL EXAMINATION OF THE FUNGUS

The morphological features observed correspond to the description of *Phytophthora hibernalis* Carne, made by Carne, (2), Moniz da Maia (7), Tucker (11), Leonian (6), and Bensaude (1), and to the description of *P. syringae* given by Klebahn (3), Tucker (11), Rosenbaum (10), Lafferty and Pethybridge (4), and others.

The hyaline mycelium was irregularly branched, 3-12μ (usually 3μ) in width, which is in accord with Carne's description.

Sporangia with flattened papilla (text-fig. 1.), as described by Tucker (11) and Bensaude (1), were obtained in our cultures in large numbers. They were found either in the culture in distilled water, or in Leonian's (6) synthetic agar and inside the corn meal agar. In the first case sporangia were grown either by Leonian's method, i.e. when mycelium was transferred from agar through pea broth to distilled water, or according to a modification by the author, i.e. by transfer of mycelium directly from potato agar or oat-meal agar culture to distilled water. In the latter case, care was taken to remove from the agar as little mycelium as possible. This mycelium was washed three or four times with sterilized distilled water before it was left to grow in the water.

Dimensions of sporangia thus obtained correspond quite well to those given by different authors, as apparent in table I.

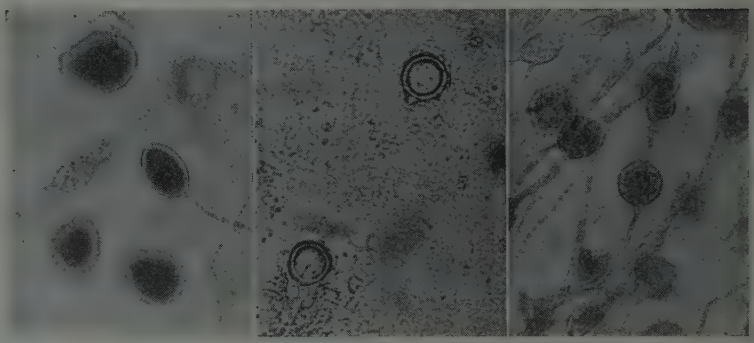
TABLE I.

Dimensions of sporangia (in μ).

Author	*Substrate*	*Extremes*	*Average*
Carne	lemon leaf tissue on potato dextrose agar	17.0-56.0×10.0-21.0	34.6×16.1
Moniz da Maia	citrus fruits	17.5-58.0× 7.5-15.0	
Tucker	agar media	28.0-41.0×15.0-33.0	34.4×17.9
Bensaude	citrus leaves	25.2-54.0×12.6-27.0	41.0×19.1
Bensaude	potato agar	23.4-39.6×11.0-18.0	30.0×14.4
Nadel	water	24.0-51.0×19.5-33.0	34.8×24.5
Nadel	Leonian's agar	25.5-51.0×15.0-27.0	36.5×20.2

If the suggestion is accepted that *P. hibernalis* is identical with *P. syringae,* then the dimensions for sporangia obtained in our work can also be compared with those given by Klebahn (3) for *P. syringae.* These dimensions are 24.0-75.0×19.0-42.0μ.

Oogonia (text-fig. 2) with yellowish membranes were obtained by the author inside the solid oat-meal and corn-meal agars, mostly very near pieces of oat or corn bran. Klebahn (3) also emphasizes that in *P. syringae* the oogonia are formed either inside the host plant or usually inside the solid substrate.



Phytophthora ~~hibernalis~~ syringae

Text-fig. 1
Sporangia with flattened papilla (x 300).

Text-fig. 2
Oogonia (x 200).

Text-fig. 3
Chlamydospores joined chain-like to one another (x 300).

The dimensions of oogonia and oospores we measured correspond quite well with the dimensions given by other authors, as is shown in table II.

TABLE II.

Dimensions of Oogonia and Ooospores (in μ).

Author	*Substrate*	*Oogonia*		*Oospores*	
		Extremes	*Average*	*Extremes*	*Average*
CARNE	Citrus leaf tissue on potato dextrose agar	22.4-56.0	40.8	22.0-45.6	35.0
MONIZ DA MAIA	culture media			22.0-42.3	
TUCKER	corn-meal agar	21.7-35.9	30.6	20.0-32.6	28.1
TUCKER	oat-meal agar	25.9-30.1	27.2	21.7-28.4	25.2
	average of various agar media		28.4		25.7
BENSAUDE	potato and oat agars	19.8-44.0	35.1	3-4μ smaller than oogonia	
NADEL	corn-meal agar	25.5-33.0	29.8	22.0-29.5	27.2
NADEL	oat-meal agar	27.0-33.0	29.9	23.0-30.0	26.8

If here again we accept the suggestion that *P. hibernalis* is identical with *P. syringae,* our figures may be compared with those obtained for the latter species by other authors, as for instance LAFFERTY and PETHYBRIDGE (4), who determined an average of 28.0μ for oogonia of *P. syringae,* and 25.4μ for its oospores.

TUCKER (11) classified *P. hibernalis* among those species of *Phytophthora* that rarely or never produce chlamydospores. We obtained chlamydospores sometimes in the mycelium grown on potato

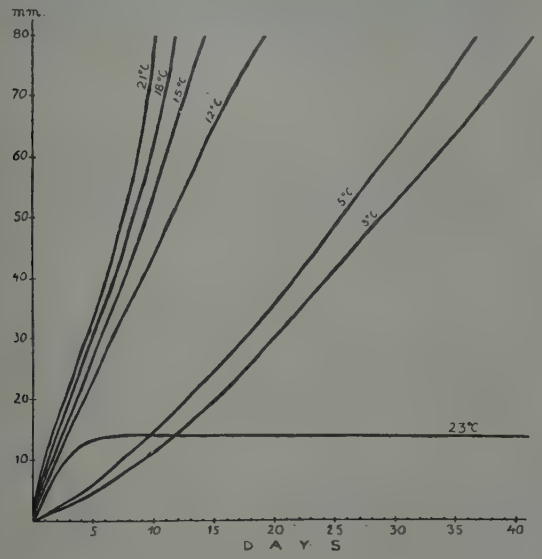
agar and very often in mycelium removed from potato agar and grown in distilled water. We also found chlamydospores on the aerial mycelium of the oat-meal agar, while on the submerged mycelium there were only oogonia. In addition, we found chlamydospores in the reisolations (on potato-dextrose agar) from lemon fruits inoculated with the fungus.

The dimensions of the chlamydospores from all the media were 15.0-25.5μ with an average of 20.4μ. The chlamydospores are chain-like, several spores being joined together (text-fig. 3). No data on dimensions of chlamydospores of *Phytophthora hibernalis* were found in literature.

II. DEVELOPMENT AS AFFECTED BY TEMPERATURE

The rate of development of the fungus was tested at the following temperatures: 3, 5, 10, 12, 15, 18, 21, 23, 25°C. *Phytophthora hibernalis* grew at all temperatures from 3°C to 23°C. At 3°C growth began only after 5-6 days, and the rate of growth was very slow. The lowest temperatures tested by other authors were 5°C (11) and 12°C (1).

The optimum of growth was between 18°-21°C which corresponds with the results of BENSAUDE (1). From 21°C to 23°C there was a quick decrease in the rate of growth. At 23°C, the diameter of the culture reached 2 cm in the first 3-5 days and thereafter there usually was no additional growth during the remainder of the 20 days of the observation (graph 1).



Graph 1. Rate of growth of *Phytophthora hibernalis* on potato-dextrose agar at different temperatures.

At 25°C there was mostly no growth at all. Growth of non-typical shriveled mycelium began in several cases and reached a diameter of a few millimeters, but then ceased quickly.

TUCKER (11) also reported that there is no growth at 25°C. In his experiments the fungus was dead after 96 hours at 30°C. LEONIAN (6) kept the fungus during six days at 27°C, which caused the death of the fungus. In accordance with BENSAUDE's (1) observations, we found the fungus dead already at a lower temperature, namely at 25-26°C.

III. DEVELOPMENT AND FRUCTIFICATION ON DIFFERENT CULTURE MEDIA

The appearance of the cultures and their rate of growth as well as their ability to produce various fructifications was tested on the following nutrient media:

1) Potato dextrose agar.

2) Oat-meal agar, as suggested by TUCKER (11) — 60 g. ground oat-meal, 17 g. agar, 1000 cc. water.

3) Corn-meal agar. as suggested by TUCKER (11) — 60 g. yellow corn-meal, 17 g. agar, 1000 cc. water.

4) Synthetic agar, as suggested by LEONIAN (6) — malt extract 3 g., yeast extract 2 g., dihydrogen potassium phosphate 0.5 g., magnesium sulfate 0.5 g., bacto agar 20 g., distilled water 1000 cc.

5) Nutrient solution, as suggested by LEONIAN (6) — proteose peptone 2 g., dihydrogen potassium phosphate 0.5 g., magnesium sulfate 0.5 g., succinic acid 0.2 g., dextrose 5 g., distilled water 1000 cc.

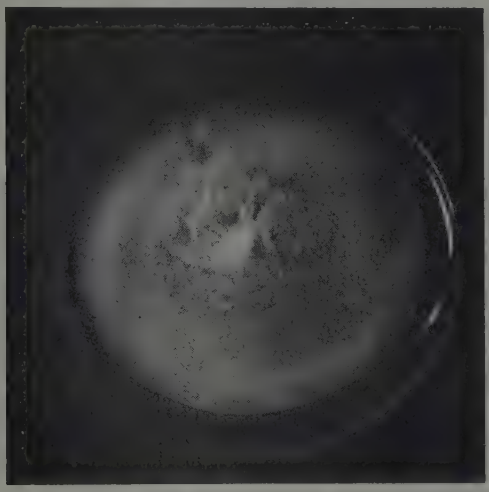
Our observations on each of these media may be summarised as follows:

On all the solid media the growth was good. The rate of growth was a little higher on corn-meal and oat-meal agars than on potato dextrose agar and on LEONIAN's agar. The cultures differed in shape as well as in the presence of various fructifications, according to the nutrient media.

1) On potato agar the mycelium was cream coloured, mostly inside the agar, producing a marble-like drawing in the shape of irregular rays which were easily visible on the transparent agar. This form of mycelial growth strongly resembles that of *P. citrophthora*. In this agar, oogonia or sporangia were never formed at any temperature and often chlamydospores only were produced (text-fig. 4).

2) On oat meal agar, the major part of the mycelium was submerged in the agar and there was only a little aerial mycelium, though this was readily apparent in the culture especially when growth began (mostly at the centre near the inoculum). On this agar, too, we observed marble-like, irregular rays which resembled those on potato

agar; the low aerial mycelium, however, was white-greyish and seemed darker because of the relatively dark background of the oat-meal agar. After about 10 days the aerial mycelium was dropped and scarcely distinguishable. The oogonia were found inside 10-14 days' old cultures, mostly on pieces of bran or near them, while only chlamydospores were found on the aerial mycelium. The number of oogonia was especially high at low temperatures, viz. at 3° and 5°C.



Text-fig. 4. Growth of *Phytophthora hibernalis* on potato dextrose agar.

3) On corn meal agar, most of the mycelium also developed inside the agar and only very little white, thin aerial mycelium developed near the surface of the agar. This mycelium collapsed, as in oat-meal agar, and after 10-14 days no aerial growth was usually seen. In such 10-14 days' old cornmeal agar cultures, oogonia were found at all temperatures. Only chlamydospores were found on the aerial mycelium.

4) On LEONIAN'S (6) synthetic agar, the shape of the culture was especially delicate and the mycelium grew only inside the agar and was seen to be thin, thread-like, emerging like rays from the centre. Inside this agar, many sporangia were found at all temperatures after 10 days.

5) On LEONIAN'S (6) nutrient solution the growth was particularly slow and no fructifications were found during the two months of observations.

IV. PATHOGENICITY TO DIFFERENT CITRUS FRUITS

The pathogenicity of *Phytophthora hibernalis* isolated from lemon fruits was tested in relation to different citrus fruits, viz. lemon, grapefruit, Shamouti and Valencia oranges, at 10, 13, 15, 18 and 23°C.

The fungus was found capable of infecting all these host species at all temperatures tested, except at 23°C. At this temperature, the virulence of the fungus did not appear sufficient to cause infection.

There were some differences in the length of the incubation period at the various temperatures. Thus, as seen in table III, the incubation period was shortest at 18°C. and longest at 10°C.

TABLE III.

Incubation period (days) on different citrus fruits at various temperatures.

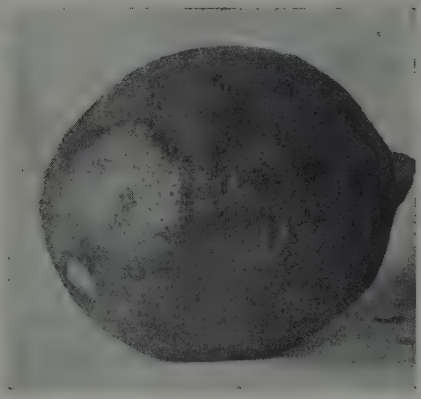
Mode of inoculation	*Host*	*Temperatures °C*			
		10	13	15	18
Inoculation into the albedo	Shamouti orange	9-10	6	5-6	4-5
	Valencia orange	10-11	6-7	5-6	6
	Grapefruit	9-10	6-7	6	5
	Lemon	10-11	6	5-6	4-5
Inoculation into the pulp	Shamouti orange	12-13	9-11	8-9	8-10
	Valencia orange	14-15	10-11	8-10	8-10
	Grapefruit	13-14	10	8-9	7-8
	Lemon	13-14	10-11	8-9	9

The length of the incubation period also varied somewhat according to the mode of inoculation. It was shorter when inoculation was made into the albedo, than when the pulp was inoculated. In the former case, inoculation proceeded as follows: A piece of peel (4 x 8 mm) was cut out to the depth of the albedo, the inoculum was inserted, the piece of peel was replaced, and the whole wound was closed with paraffin. The second mode of inoculation consisted of insertion of a needle into the pulp, introduction of the inoculum, and sealing of the wound with paraffin. The differences in the length of the incubation period following inoculation by these two methods were apparent especially at the optimum temperature of 18°C. However, the length of incubation period, by either method of inoculation, did not differ at any temperature in the various hosts tested. (Table III).

Appearance of the rot

MACROSCOPICAL. In all the hosts tested, the rot was more or less firm. In lemon (text-fig. 5), Shamouti and Valencia orange, affected parts were coloured more or less dark shades of brown. In grapefruit, there was sometimes no browning, especially where relative humidity was high. In both Shamouti and Valencia oranges, the rot appeared as a continuous, discoloured zone. In grapefruit and lemon,

however, the rot appeared mostly as separate patches, which finally coalesced to form one continuous zone (text-fig. 5). In general, there is no difference between the appearance of the rots produced by *P. hibernalis* and by *P. parasitica* and *P. citrophthora.*



Text-fig. 5. Lemon infected by *Phytophthora hibernalis.*

MICROSCOPICAL. In cross sections of the peel of rotten fruits, the abundant mycelium was found to be mostly intercellular and very rarely intracellular. BENSAUDE (1) states that the mycelium is intracellular in the epidermis of the fruit peel and in the two layers beneath it, but is intercellular in the remaining tissues. We could not observe this distinction in the Shamouti orange peel we examined.

V. PATHOGENICITY TO DIFFERENT HOST PLANTS AS A MEANS OF DIFFERENTIAL DIAGNOSIS

In order to ascertain the identity of *Phytophthora hibernalis* the pathogenicity of the fungus was tested in relation to fruits of apple, eggplant and tomato, and to potato tubers. All this was based on TUCKER's (11) study. Ten fruits or tubers were inoculated in each case.

Apple. In agreement with TUCKER's (11) results, *P. hibernalis* was virulently pathogenic to apples. Concerning the rate of development of the infection, we obtained the same results as TUCKER (11), i.e. the diameter of the rotted fruit, 19 days after inoculation at 10°C. was 35 mm; the same diameter of rot was obtained by us at 13°C already after 10 days.

Eggplant. TUCKER (11) classified *P. hibernalis* in the group of species of *Phytophthora* non-pathogenic to eggplant fruits, basing on his observation that the fungus did not infect eggplant fruits at

10°C during one week. The author stored eggplant fruits at 10°C for a longer period and obtained infection (100 per cent) after 10-12 days.

Tomato. TUCKER (11) did not test the pathogenicity of *P. hibernalis* to tomato fruits; we obtained infection (100 percent) at 10°C after 10-12 days.

Potato tubers. TUCKER (11) classified *P. hibernalis* in the group of fungi not pathogenic to potato tubers, basing on the fact that he did not achieve infection of the tubers at 10°C during 20 days.

According to our results *P. hibernalis* can be pathogenic to potato tubers; the success of infection seems to depend on the physiological state of the tubers. Dormant tubers appear more readily infected than tubers ready to sprout: In cases in which no infection occurred the tubers were found to be sprouting.

VI. THE APPLICATION OF TESTS OF DIFFERENTIAL GROWTH FOR DIFFERENTIAL DIAGNOSIS

LEONIAN (5, 6) has used the differential growth on various substrates for diagnostic purposes. Of the different substances he used, we applied: a) anhydrous potassium carbonate and b) malachite green, to test their effect on the growth of *Phytophthora hibernalis.*

a) Following LEONIAN (6), we grew the fungus on bactodextrose broth wih he addition of 0.25 percent of anhydrous potassium carbonate. In agreement with LEONIAN's (6) results, *P. hibernalis* developed on this medium, but the rate of growth was slower than on other agar media.

b) LEONIAN (5) has grown *P. hibernalis* in nutrient solution with addition of malachite green at the rate of 1:8,000.000 and 1:4,000.000. In these solutions the fungus showed fair growth. In a later publication, however LEONIAN (6) reported negative results with the same nutrient solution with addition of malachite green in concentrations of one part to 2,3,4,8 and 12 million parts, respectively.

We grew *P. hibernalis* in the same nutrient solution with the addition of malachite green in proportions of 1:4,000,000 and 1:10,000.000. We did not find any growth at 1:4,000.000, while very little sporadic growth was achieved (after 3 weeks) at 1:10,000.000.

LEONIAN's results agree with ours in showing that differential growth after addition of malachite green cannot be used as a factor for determination of *Phytophthora hibernalis.*

VII. SUMMARY

A species of *Phytophthora* isolated in Palestine from lemons and Shamouti oranges was identified as *P. hibernalis* Carne.

Morphological examinations of the fungus were made and their results compared with those described in the literature. Chlamydo-

spores, which were not so far mentioned in the literature on *P. hibernalis*, have been described.

The rate of development of *P. hibernalis* was tested at a range of temperatures from 3 to 25°C. It was found that the fungus developed between 3 and 23°C, with an optimum between 18-21°.

The rate of growth of the fungus and its ability to produce different fructifications was tested on various nutrient agars, viz. potato dextrose, oat-meal, corn-meal, solid synthetic agar, and on a nutrient solution.

The pathogenicity of *P. hibernalis* was studied in relation to different citrus fruits: it was found that *P. hibernalis* isolated from lemon fruits may cause rot not only on lemon, but also on both Shamouti and Valencia oranges and on grapefruit.

For further differential diagnosis we made:

a) inoculation of apple, eggplant and tomato fruits and of potato tubers, which were all successful.

b) tests of the differential growth made by the fungus on nutrient media with the addition of 1) anhydrous potassium carbonate, and 2) malachite green.

The results of these studies confirmed the fungus to be *P. hibernalis*.

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THE MODE OF INFECTION OF SHAMOUTI ORANGES BY DIPLODIA *)

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INTRODUCTION

Under ordinary conditions of storage or shipping, diplodia stem-end rot begins naturally, as indicated by its name, at the stem-end of the fruit, 2-4 weeks after picking.

In previous investigations on the occurrence of *Diplodia* on oranges, spores and mycelium of the fungus have already been found present on the fruit shortly after fruit set (1, 3).

Evidence that diplodia stem-end rot develops mainly from the infected stem-end of the orange, is furnished by the fact, that the incidence of stem-end rot is markedly lowered by debuttoning (4, 5, 6, 7, 8).

The experiments reported here were to show (a) whether *Diplodia* established on any part of the stem-end is able to induce fruit rot, and, (b) whether such rot may be induced through the rind. The latter point was considered important with regard to possible contact infection of fruit by *Diplodia* during shipment.

The experiments extended over three seasons, viz. 1938/39, 1939/40, and 1943/44 .

METHODS

Inoculation

In 1938/39, inoculations with and without wounding were made (a) on various parts of the stem-end, viz. on the freshly cut fruit stalk, on both upper and lower sides of the sepals, and on the base of fruit after debuttoning; (b) laterally through the rind into the pulp. Inoculations with wounding were made by placing the inoculum by means of a thin sterile pin into the tissue; inoculations without wounding were made by placing the inoculum on the tissue. The experiment was carried out once in mid-April.

In 1939/40 inoculations were made only without wounding on the same parts of the stem-end as in the 1938/39 experiments, since

*) Contribution from Citrus Fruit Wastage Investigations sponsored by the Department of Agriculture of the Palestine Government.

the inoculations after wounding in the 1938/39 season gave positive results under all the various conditions tested. Furthermore, investigations were included on the effect on subsequent fruit rot of the kind of wound resulting on the fruit stalk from the use of different types of clippers for picking. The clippers used were (a) ordinary clippers which cut the stalk like scissors and leave a smooth surface, and (b) Harvey clippers which pinch the stalk off, leaving a rough surface. To ascertain whether the state of the wound (fresh or dry) affects infection, inoculations were made both on freshly cut stalks and on cuts made on the previous day.

In 1943/44 inoculations through the rind were made by pricking the latter with two kinds of needles; a very thin (entomological needle) and a somewhat thicker one. The various modes of inoculations are listed in table II, except the inoculations into the flavedo (a) through the oil glands and (b) between the oil glands, that were carried out with the thin needle only. The experiments were carried out in mid-February.

"Standard" inoculations, consisting of the introduction of the inoculum by a needle into the base of the fruit after debuttoning, and subsequent sealing with paraffin, served for comparison.

Inocula

In 1938/39 three inocula were tested: (i) a mash of culture isolated from an orange naturally infected with diplodia stem-end rot, (ii) dry spores collected from branches of an orange tree affected with diplodia blight, and (iii) a water suspension of those spores.

In 1938/39 only the water suspension of spores was used as an inoculum, since the success of inoculation without wound was not found to be markedly influenced by the different inocula either in the 1938/39 experiment or in other investigations (2). In 1943/44 both the spore suspension and the culture mash were used.

Relative humidity

In 1938/39 the inoculated fruit was kept at 20-22°C at relative humidities of either 80-90 per cent., when it was wrapped in ordinary tissue paper, or 100 per cent., when the infection court was covered with sterile cotton (to which sterile water was added every second day) and the fruit was wrapped in cellophane paper. — In 1939/40 the fruit was kept at 18°C, either at 80-90 per cent. relative humidity or in saturated air containers: the latter were used because the method of maintaining high humidity in 1938/39 by means of wet cotton proved unsatisfactory and conducive to mould infection.—In 1943/44 inoculated fruit was wrapped in ordinary tissue paper and kept at 18-19°C and 80-90 per cent. relative humidity.

INOCULATIONS THROUGH THE STEM-END

Inoculations through various parts of the stem-end

Inoculation with wounding was always 100 percent. successful, no matter to what part of the stem-end the inoculum was applied.

Without wounding, inoculations were also generally positive, but there were appreciable differences in the success of inoculation between the various parts of the stem-end, the success being lowest in the inoculations on "base of fruit with dry spores" (1938/39), on the "upper surface of sepals", and on "freshly cut fruit stalk by ordinare clippers" (1939/40, *cf.* table I).

In 1938/39 the incubation period in most cases did not differ appreciably in length, whether the inoculum was applied to one part of the stem-end or another. However, the incubation period in general was shorter (9-13 days) with fruit of the group inoculated with wounding, and longer (12-26 days) in unwounded fruit. In 1939/40 the incubation period of inoculations without wounding, on all parts of the stem-end, lasted 11-26 days, and was much longer than that with wounding (5-15 days).

The inoculum

The differences in the effect of various inocula on the success of inoculation were masked at high humidity, because all inoculations then succeeded. But at 80-90 percent. relative humidity, in inoculations without wounding, there were some differences: In the 1938/39 tests, culture mash inoculum induced 100 percent. rot when applied to the stalk or the base of the fruit, while dry spore inoculum induced 60 percent. rotting in the cut stem, and no rot at all in the base of fruit. These differences may tentatively be explained by assuming that the success of inoculation without wounding is likely to depend on the stage of development of the fungus. Dry spores may be checked in their germination and subsequent penetration into the healthy tissue, whereas wet spores and mycelium have better conditions for penetration. In the 1939/40 inoculations, with water suspensions of spores, the results, at the same time of the season as in 1938/39, were more irregular; but 60 percent. success was, for example, gained on the base of fruit (one month after inoculation). As regards irregularities in the success of inoculation on the base of fruit, it may be suggested that this could be due to the degree of wounding or the state of the base after removal of the button. The effect of various inocula on the length of the incubation period was not consistent, as this period was irregular.

Humidity

At 100 percent. relative humidity in saturated air containers inoculations were so uniformly successful that all effects of other factors (part inoculated, inoculum, season etc.) were largely or completely masked. At 80-90 percent. relative humidity, in inoculations

TABLE I.

Infection of the stem end of Shamouti oranges by Diplodia; percentage of rot after 1 and 2 months' storage at 80-90 percent. relative humidity, following various modes of inoculation at various times of the season
(*inoculation by suspension of spores in water*)

Mode of inoculation	November		December		January		February		March	
	after		after		after		after		after	
	1 month	2 months	1 month	2 months	1 month	2 months	1 month	2 months	1 month	2 months
On fruit stalk freshly cut by ordinary clippers*)	0	0	0	30	0	30	20	40	20	60
On fruit stalk cut one day before by ordinary clippers*)	0	0	0	40	0	20	60	80	70	100
On fruit stalk freshly cut by Harvey clippers*)	0	0	10	40	20	70	100	100	100	100
On fruit stalk cut one day before by Harvey clippers*)	0	0	0	30	10	30	80	80	80	90
On upper surface of sepals*)	10	10	0	0	10	60	20	20	30	40
On underside of sepals*)	0	0	20	50	0	70	40	60	40	90
On base of debuttoned fruit*)	10	10	20	40	0	10	0	0	60	100
Standard inoculation — by needle, on base of debuttoned fruit, sealed with paraffin	100	100	100	100	100	100	100	100	100	100
Control — untreated	0	0	0	10	0	0	0	10	0	40

*) inoculation without wounding

without wounding, different effects in the success of inoculation were often obtained by the various modes of infection, inocula, modes and seasons of picking, etc. (cf. above and the following paragraphs). Besides the success of inoculation, the length of the incubation period was shorter in saturated air than at 80-90 percent. relative humidity. In March, for example, incubation periods in closed containers ranged from 7 to 17 days only, as against 21 to 26 days at 80-90 percent. relative humidity.

Seasons

As indicated by the data in table I, the success of inoculations without wounding varied with the season. In November-January, the percentage of decayed fruit one month after inoculation was only 0-20, and after 2 months did not exceed 50 and 70 percent., in the inoculations made in December and January, respectively. Later in the season, however, in the February and March inoculations, the percentage success was higher, and inoculations on the cut fruit stalk, for instance, were 100 percent. successful after only one month.

The length of incubation periods was irregular throughout the season, regardless of the mode of inoculation. But in November-January this period was longer (25-29 days) than in February-March inoculations (11-26 days).

Mode of picking (clipping)

The type of clippers used in picking the fruit affected the results of inoculations on the cut fruit stalk. The percentage rot was higher and the incubation period shorter with Harvey clippers than with ordinary clippers. The differences were marked after one month of storage, especially in the fruit inoculated in February (table I).

With ordinary clippers, inoculation of freshly cut fruit stalks resulted in somewhat lower percentages of rot and longer incubation periods than inoculation of stalks cut one day previously. With Harvey clippers the results were inconclusive in this respect.

INOCULATION THROUGH THE RIND

In 1938/39 all inoculations through the rind into the pulp were successful with all inocula, at either level of relative humidity. The incubation period lasted only 1-3 days. — Inoculation of the rind without wounding gave negative results, except in a few instances, where fruit rotted after inoculation with a culture mash and covering with wet cotton.

In 1943/44 the first inoculations by a thin needle induced but a small amount of rot. The "window" inoculation and inoculation into the pulp, which served for comparison, were successful. — Subsequent inoculations with a thicker needle were more successful, and all modes of inoculation then reduced rotting (table II). The percentage of rot was higher with the culture mash than where the water

TABLE II

Infection of the r i n d of Shamouti oranges by Diplodia; percentage of rot resulting from various modes of inoculation with two inocula after 10 *days' storage* (1943/44)

(*inoculation by thick needle*)

Mode of inoculation	*I n o c u l u m*	
	spore suspension in water	*culture mash*
into the albedo, through an oil gland; sealed with paraffin	90	100
do., not sealed	40	80
into the albedo, between oil glands; sealed with paraffin	40	90
do., not sealed	50	100
scratching by the needle up to the albedo	30	70
"window" inoculation: patch on rind, 10 by 5 mm, 3 mm deep; sealed with paraffin	100	90
laterally into the pulp; sealed with paraffin	100	100

suspension of spores was used as inoculum (table II). The incubation period was relatively short, most of the fruit rotting in the course of one week.

SUMMARY

Inoculations of *Diplodia* (with and without wounding) were made on various parts of the stem-end of Shamouti oranges, viz. cut fruit stalk, sepals, and base of fruit, and laterally on the rind. Fruits inoculated by different inocula were kept at relative humidity levels of 100 and 80-90 per cent.

Stem-end. — The influence on infection has been described of inoculation on various parts of the stem-end and of the use of various inocula and various clippers in the course of the whole season.

All inoculations by *Diplodia* with wounding on various parts of the stem-end were successful at both relative humidities.

The success of inoculations without wounding greatly varied but was more pronounced at the higher than at the lower relative humidity. Furthermore, the success of these inoculations was influenced by fruit maturity, being higher in the second part of the season (February-March). The amount of rot and its rate of development were also noticeably higher in fruit picked by Harvey clippers than in that picked by ordinary ones.

Rind. — All inoculations by *Diplodia* through the rind were successful. The percentage of rot was higher when the inoculum was applied with a ticker needle than when a thin needle was used.

Inoculations without wounding on the surface of the fruit were in general unsuccessful; they were partly positive only at high humidities when culture mash inoculum was used.

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THE INCUBATION PERIOD AND RATE OF DEVELOPMENT OF DIPLODIA IN SHAMOUTI ORANGES *)

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INTRODUCTION

The fungus *Diplodia* was found to be present on the stem-end of Shamouti oranges at a very early stage of fruit development, shortly after fruit set (6, 7).

Diplodia stem-end rot of oranges occurs in nature after picking at the beginning of the picking season and especially towards its end, as the temperatures prevailing at both these periods favour the development of the fungus. The incidence of *Diplodia* rot increases in the course of the picking season in accordance with changing climatic conditions, especially with the rise of temperature, and with advancing maturity of the fruit (1, 2, 3, 4, 5, 8). The rate of development of the rot on the fruit until its decay during the period of shipment may determine the extent to which the disease may spread by contact to neighbouring fruits.

An accurate knowledge of the length of incubation period of *Diplodia* in Shamouti oranges at various temperatures will enable us to determine the conditions under which the fruit should be kept from picking time throughout preshipment handling and during shipment, to control stem-end rot.

PLAN AND METHODS

The effect of temperature on the length of the incubation period and on the subsequent rate of development of diplodia stem-end rot in the fruit was studied over three consecutive picking seasons, viz. 1938/39, 1939/40 and 1940/41.

The temperatures tested throughout the experiments were: 7, 14, 18, 25, 30, and 35°C.

The inocula used were: (a) a mash of culture isolated from orange fruit naturally affected with diplodia stem-end rot; (b) dry spores collected from orange twigs infected with diplodia blight; (c) a water suspension of these spores; (d) a mash of young mycelium (3 days) developed from spores; (e) a mash of sporulating culture from the same source.

*) Contribution from Citrus Fruit Wastage Investigations sponsored by the Department of Agriculture of the Palestine Government.

Inoculum (a) was introduced by pin pricks either to a depth of 2-3 mm. into the cut stalk of the fruit, or to a depth of 3-5 mm. into the base of fruit; inocula (b)-(e) were introduced into the base of fruit only.

The fruit was wiped with alcohol 95% before inoculation and the base of fruit was disinfected (with alcohol) after debuttoning, and was flamed. After inoculation the wound was sealed with paraffin, and the fruit was wrapped in ordinary tissue paper and incubated. Re-isolations of the fungus from inoculated fruits were made in some doubtful cases. The fruit used in the experiments originated from a young grove known to have a low natural incidence of diplodia stem-end rot. It was inoculated on the day of picking or on the next day. Each experimental item comprised ten fruits. The experiments lasted in the first two seasons from October to March, but began in the last season only in December, when the fruit was fully mature. The experiments were carried out at monthly intervals.

RESULTS

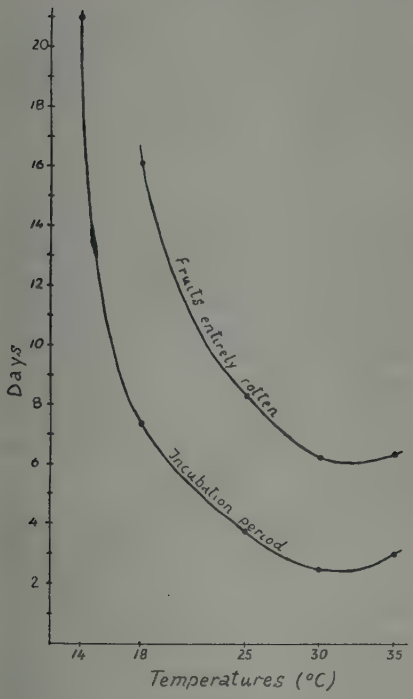
The length of the incubation period and of the period elapsing from inoculation until the fruit was entirely decayed varied to some extent in each of the three seasons covered by this study. Advancing maturity of the fruit in the course of the season also sometimes affected the length of the incubation period.

Effects of temperature and fruit maturity

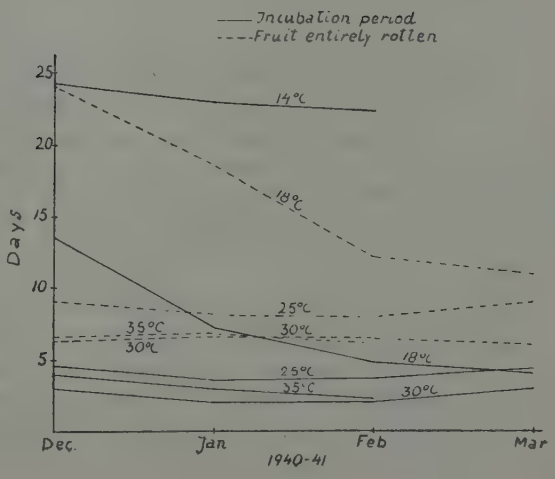
The effect of temperature on the rate of incubation and subsequent development of *Diplodia* on Shamouti oranges is exemplified by the data presented by graph 1. These data were recorded after inoculation of the base of the fruit with water suspension of spores, which gave regular results; similar results, with slight variations, were obtained with the other inocula and modes of inoculation tested. The effects of advancing fruit maturity are shown in graph 2.

The incubation period was shortest at 30°C, though differences in the length of this period were not well-marked between 25° and 35°C at any part of the season (35°C was not tested in March); at these temperatures the incubation period lasted throughout the season only 2 to 4½ days, while 6 to 8½ days elapsed between inoculation and complete decay of the fruit.

At 18°C the incubation period was generally longer than at 25-35°C, and its length was influenced by the state of maturity of the fruit. Early in the season (December) the incubation period at this temperature extended over 14 days, but in March only over 4 days. In March there was thus little difference between the length of incubation periods at 18°C and 25°C. The subsequent rate of development of the rot at 18°C until the fruit had completely decayed, depended similarly on fruit maturity, 10 days being required in December and 7 days in March.



Graph 1. The effect of temperature on the length of the incubation period of *Diplodia* in Shamouti oranges and on the period elapsing until inoculated fruit decays entirely.



Graph 2. The effect of advancing fruit maturity throughout the season on the length of the incubation period of *Diplodia* on Shamouti oranges and on the period elapsing until inoculated fruit decays entirely.

At 14°C development of the rot was slow and erratic. The length of the incubation period in December-February (this temperature was not tested in March) extended over 22-24 days; subsequent development of the rot was so slow that none of the fruits had entirely decayed within the 4 weeks covered by our records.

At 7°C diplodia stem-end rot failed to develop.

Effects of various inocula

The results obtained with all other inocula, viz. a culture isolated from a decayed orange, dry spores, and young and old mycelium derived from these spores, closely resembled those obtained with the water suspension of spores. Table I indicates the relative lengths of incubation periods recorded at 25°C after application of various inocula to the base of fruit in January and March.

TABLE I.

Length of incubation periods (in days) after inoculation of Shamouti oranges with various inocula of Diplodia, at 25°C.

(Inoculated on the base of fruit, 1940/1941)

Inoculum	*January (days)*	*March (days)*
Mash of culture isolated from Diplodia fruit rot	4.1	3.0
Dry spores collected from twig blight	4.0	3.9
Water suspension of spores collected from twig blight	3.9	3.7
Mash of culture derived from twig blight (young mycelium)	3.6	2.0
Mash of sporulating culture from twig blight	3.6	3.0

SUMMARY

The length of the incubation period and of the period between inoculation and total fruit decay was studied in three seasons on Shamouti oranges inoculated with *Diplodia natalensis*.

The level of temperature and sometimes the stage of fruit maturity affected the length of these periods, while no marked differences resulted from the use of five different inocula.

The most favourable temperatures for rot development in shamouti oranges ranged between 18° and 35°C.

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ANATOMICAL STUDY OF THE BUTTON AND RIND OF SHAMOUTI ORANGES IN RELATION TO THE MODE OF INFECTION BY DIPLODIA *)

By

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INTRODUCTION

It was shown in previous experiments that *Diplodia*, either in the form of spores or in the form of mycelium, is capable of inducing fruit rot in Shamouti oranges after inoculation, with or without wounding of any part of the stem-end (including base of fruit) and after inoculation through the injured rind (1).

The aim of this study was to investigate the courses of the fungus (a) in the tissues of the stem-end, after inoculation without wounding, and during its passage from the button to the fruit, (b) in the tissues of the rind after inoculation with wounding.

METHODS

The various parts of the stem-end, viz. cut fruit stalk, upper surface and underside of sepals, and the base of fruit were inoculated without wounding, and the rind was laterally inoculated by pin pricks penetrating 2-3 mm into the albedo. The inoculated fruit was incubated at 20-22°C. After various periods, the inoculated parts with their surrounding tissues were fixed either in alcohol-acetic acid-formaldehyde or in dioxan, one or two samples being fixed before any sign of rot appeared, and one after the first sign of rot was observed. Thus the rind and the base of fruit were fixed 2 and 5 days after inoculation, stem-ends inoculated on the cut fruit stalk — after 5, 9 and 20 days, and those inoculated on the sepals — after 2, 5 and 23 days.

The inocula used were either (a) dry spores collected from branches of an orange tree affected with diplodia blight, or (b) a mash of culture isolated from diplodia stem-end rot of an orange fruit.

The infection court was held at a high relative humidity, being covered with a sterile wet cotton.

The microtome sections (10-15μ) were stained either with cotton blue or with Pianeze III B.

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*) Contribution from Citrus Fruit Wastage Investigations sponsored by the Department of Agriculture of the Palestine Government.

RESULTS

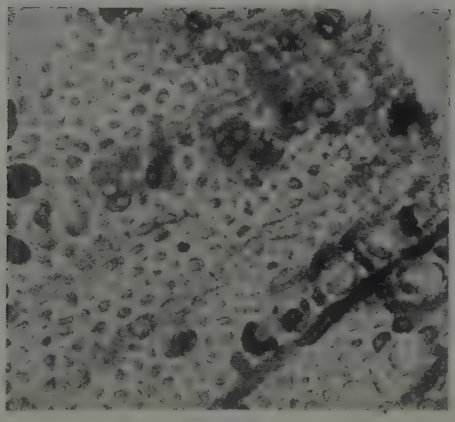
The anatomical examination indicated the presence of mycelium in various parts of the stem-end and in the rind, the spread of the fungus through different tissues, and its rate of development.

The results given here are exemplified in examinations of tissues inoculated with dry spores of *Diplodia;* the culture mash inoculum gave similar results.

Stem-end

Inoculation (without wounding) on the cut fruit stalk. After 5 days germinating spores and hyaline mycelium are present on the cut surface. The mycelium penetrates the stalk up to 1 mm.

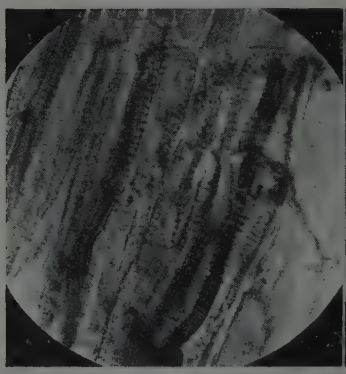
After 9 days the entire stem-end, including the base of fruit, and the space between the button and the base are filled with hyaline mycelium. This is present in all tissues except the fibres in the xylem, the density of which probably inhibits free mycelial growth. In the xylem the mycelium is present mainly in the water conducting vessels; in the broad water-conducting vessels 3-4 hyphae are seen, and sometimes vessels seem to be blocked by mycelium (text-figs. 1, 2). In the pith and medullary rays of the fruit stalk (text-figs. 1, 3) and in the parenchyma of the sepals the mycelium is both intercellular and intracellular.



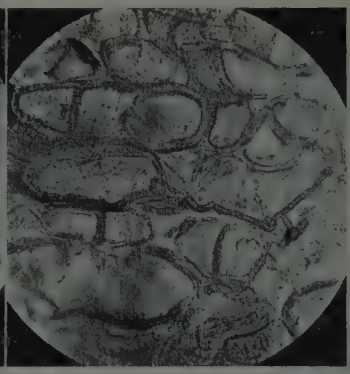
Text-fig. 1
Transverse section of the fruit stalk infected by *Diplodia.* Mycelium in the water conducting vessels and in the medullary rays.

At this stage, five and nine days after inoculation of the cut fruit stalk, the stem-end still remains green and externally healthy, and no sign of rot appears on the fruit.

After 20 days first signs of stem-end rot begin to appear in the stem-end region. The entire stem-end including the base of fruit is then filled with hyaline and brown mycelium.



Text-fig. 2. Longitudinal section of the fruit stalks. Mycelium in the water conducting vessels.



Text-fig. 3. Transverse section of the fruit stalk. Mycelium in the pith.

Inoculation (without wounding) on the upper surface of sepals. After 2 days germinating spores with germ tubes more or less developed, are present on the upper surface of the sepals.

After 5 days a hyaline mycelium is present in the parenchyma of the sepals and in the bark of the fruit stalk. The mycelium is particularly abundant near the epidermis and hypodermis of the upper surface, i.e. close to the infection court. No mycelium is found in the xylem and in the pith of the fruit stalk.

At these stages (after 2 and 5 days) the stem-end remains externally healthy, and no sign of fruit rot appears.

After 23 days the entire stem-end, including the base of the fruit, is filled with mycelium. In the parenchyma of the stem-end and of the base of the fruit the mycelium is always intercellular and intracellular. The conducting vessels of the stem-end and of the base of fruit are filled with mycelium. In the sepals, in the bark of the fruit stalk, and in the base of the fruit the mycelium is mostly hyaline, while that in the water-conducting vessels and in the pith of the stalk is mostly brown.

At this stage first signs of rot begin to appear on the fruit. Sometimes pycnidia of *Diplodia* were found on the sepals and in the axil near the base of the fruit.

Inoculation (without wounding) on the underside of sepals. No important differences were observed between the courses of infection on the underside, as compared with the upper side, of sepals.

Inoculation (without wounding) on the base of fruit. After 2 days germinating spores are present, and a hyaline mycelium enters the inner mesocarp (albedo) near the infection court.

After 5 days the mycelium penetrates the tissue to a depth of up to 2-3 mm, being intercellular and intracellular in the parenchyma of the inner mesocarp, and growing inside the water-conducting vessels. The mycelium penetrates the vascular bundles a little deeper than the surrounding parenchyma.

Rind

After 2 days germinating spores are present in the puncture made by the inoculating pin, and a hyaline mycelium penetrates the entire depth and 2-3 mm of the surrounding tissue of the inner mesocarp (albedo). It is also present in the epidermal and hypodermal cells, and in the stomata. The mycelium spreads intercellularly and intracellularly. The rind at this stage remains firm and without any discoloration.

After 5 days the entire inner mesocarp (one cm. wide) is filled with hyaline, and partly with brown, mycelium. This is intercellular and intracellular in the inner mesocarp and in the vascular bundles passing it. At this stage the rind around the infection court is somewhat soft.

SUMMARY

The anatomical study of the course of penetration of *Diplodia* into Shamouti oranges confirmed the experimental study (1), i.e. that the fungus is able to enter the fruit either from each part of the stem-end inoculated without wounding (cut fruit stalk, both upper surface and underside of sepals, and the base of fruit), or from the rind inoculated after wounding.

The first stages when the fungus was discovered in the microscopical sections of tissues surrounding the infection courts occurred: 2 days after rind inoculation (with wounding), 5 days after inoculation (without wounding) of sepals and base of fruit, and 9 days in the case of the cut fruit stalk.

At the first stages of fungus penetration, although an abundance of mycelium was present in the tissues after inoculation, the inoculated parts, i.e. stem-end or rind, remained healthy, the former being green and fresh, the latter firm and without discolouration.

The spread of mycelium from the inoculated parts of the stem-end was through the entire stem-end into the fruit, and that of the inoculated rind filled the entire depth of mesocarp (flavedo and albedo) under the inoculated place and its surroundings.

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INTERNAL RUST SPOT OF POTATOES *)

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INTRODUCTION

This paper deals with that pathological condition of potato tubers which has variously been described as "internal rust spot" or "internal brown flecks" (1, 2, 3). This condition was first observed in Palestine on a larger scale in summer 1938, when potato tubers, especially those of the Arran Banner variety, were much affected and their market value greatly reduced. Some of these observations have been described in an earlier paper (5).

Our study of internal rust spot consisted 1) of surveys of the occurrence of this condition in Palestine in various seasons and on various varieties, and 2) of field experiments to determine its transmissibility from set tubers to daughter tubers.

To ascertain the presence of rust spots the tuber tissue was examined, approximately 2 cm below the apex, by cutting the tuber transversely or by withdrawing a tissue cylinder by means of a cork borer. Although in all the investigations of internal rust spot that have so far been reported from abroad the tubers were always cut lengthwise, we preferred to cut them transversely as this facilitates determination of the spots when few in number. The tubers were examined shortly after lifting, 100 tubers each of large size (above 100 grammes), medium size (30-100 grammes) and small size (below 30 grammes) being examined in each crop.

The above studies were supplemented by histological examinations. Sections made from potato tubers by the freezing microtome and by hand were stained with Sudan III in glycerol and were heated. To determine whether or not thickening of the corners of the cells in affected tissue was due to suberization, tests were made with concentrated KOH with or without heating.

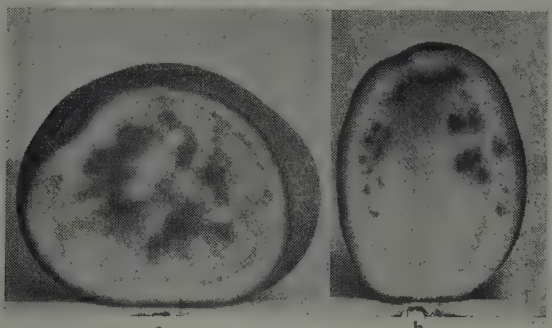
DESCRIPTION

Macroscopical

The tubers appear outwardly sound. When affected tubers are cut they show, especially near their apex, spots ranging in colour from light golden brown to reddish brown or dark brown. The size of these spots varies from that of a mere pin point to that of a pea.

*) Received for publication in August 1945.

Individual spots may coalesce to form larger affected areas. The spots are irregular in shape, but tend to be roundish and without well-marked delimitations. In transverse sections of affected tubers the spots appear scattered over the whole tissue up to 1-2 mm. below the peel (cf. text-fig. 1a), but sometimes the spots are seen to concentrate in one part of the tuber only. In longitudinal sections the spots can be seen to extend from the top end to about the middle of the tuber or slightly below that (text-fig. 1b). No spots were ever observed near the heel end, except in the variety Invincible where this end was also affected. The affected tissues did not deteriorate, so that no cavities were formed and the tubers did not rot. Neither fungi nor bacteria were ever observed in sections of affected tissue, and cultures made from such tissue were always negative.



Text-fig. 1. Internal Rust Spot of potato tubers. (a) Transverse section. (b) Longitudinal section.

When affected tubers are cooked various changes take place: the spots turn darker than before and they form hard, corky masses. The appearance of such tubers, when cut across, is not attractive but their taste is not much inferior to that of normal tubers. On the other hand, dehydration has a much more pronounced effect on tubers affected by internal rust spot: their tissue then readily breaks up and they are almost useless.

The storage of affected tubers presents no special problems and they are not more liable to decay than normal tubers. The incidence of internal rust spot does not increase during storage, whether the tubers are simply stored in sand or clamps or whether they are kept for long periods in cold storage.

The symptoms of this disease agree with those described in various countries as non-parasitic internal necrosis of potato tubers.

Microscopical

The cells of affected tissue are smaller than normal and irregular in size. In sections of the centre of rust spots we observed groups of small cells with thick walls and with the spaces between the cells

filled with cork. At the periphery of the spots there are mostly layers of narrow, elongated, rectangular, and parallel cells typical of cork tissues which isolate the affected from the normal tissue. These findings are similar to those described by PASINETTI (4) in his histological studies on "Eisenfleckigkeit". Microchemical tests showed suberin in the cell walls of affected tissues, especially in the peripheral cell layers of the lesions.

In the rust spots themselves and in the tissue surrounding them there are fewer starch grains than in sound tissue.

SURVEY OF THE OCCURRENCE OF INTERNAL RUST SPOT IN PALESTINE

A survey of the occurrence of internal rust spot in Palestine was made from 1939 to 1942 and in 1944/1945. The survey covered many varieties grown at various seasons on light and heavy soil, and irrigated as usual under local conditions, i.e. by overhead irrigation at 3-5 days', or by furrows at 7-10 days' intervals. The three crops of potatoes generally grown in Palestine are the winter crop sown in November-January and lifted in April-May; the spring crop sown in February-March and lifted in June-July; and the autumn crop sown in August-September and lifted in November-January.

The results of this survey, as far as soil types, growing seasons and varietal susceptibilities are concerned, are summarized in table I.

Soil types

No definite connection could be established between the occurrence of internal rust spot and the type of soil, whether heavy or light.

Growing seasons

The occurrence of internal rust spot differs greatly at different seasons. No affected tubers have been found on any variety in autumn crops sown in September and lifted in November-January. In the winter and spring crops sown between January and March and lifted from May to July, the date of lifting has a definite bearing on the occurrence and severity of the disease in many varieties. No rust spots have been observed on crops lifted up to mid-June, except in the variety Invincible. The incidence of disease increased in the crops lifted during the second half of June and was most severe in the crops lifted last, in July. The variety Arran Banner, for instance, in 1945 yielded 30% affected tubers among those lifted during the second half of June, but as much as 80% among those lifted in July.

TABLE I.

The occurrence of Internal Rust Spot on potatoes in Palestine.

Variety	*Year*	*Soil type*	*% affected tubers lifted in* Nov.-Jan.	April to mid-June	15th-30th June	July	*Grade of susceptibility*
Alpha	1939	heavy	0	0	—	—	
Arran Banner	1939	heavy	0	—	—	22-35	susceptible
	1940	light & heavy	0	0	40	75	
	1941	light & heavy	0	0	30.5	35	
	1942	light & heavy	0	0	50	—	
	1944	light & heavy	0	0	0	50	
	1945	light & heavy	0	0	30	80	
Arran Chief	1939	heavy	—	—	—	0	highly resistant
Arran Consul	1939	heavy	—	—	—	0	highly resistant
Arran Crest	1939	heavy	—	0	—	—	
Arran Pilot	1939	heavy	0	0	—	—	
Benlomond	1939	heavy	—	—	—	10	resistant
Bintje	1939	heavy	0	0	—	—	
British Queen	1939	heavy	—	—	—	0	highly resistant
Champion	1941	light	—	—	—	100	highly susceptible
Eclipse	1939	heavy	—	0	—	—	
Epicure	1939	heavy	0	0	—	—	susceptible
	1944	heavy	0	—	10	10	
	1945	heavy	—	—	—	10	
Gladstone	1944	heavy	0	—	0	—	highly resistant
	1945	heavy	—	—	—	0	
Glasgow Favourite	1939	heavy	—	—	—	0	highly resistant
Inverness Favourite	1939	heavy	—	—	—	0	
Invincible	1941	light	0	—	—	100	highly susceptible
	1942	light	0	53	70	100	
Kerr's Pink	1944	heavy	0	—	—	30	
	1945	heavy	—	—	—	20	susceptible
Konsuragis	1939	heavy	—	—	—	0	highly resistant
Majestic	1939	heavy	0	—	—	21	resistant
Red Skin	1944	heavy	0	—	—	50	susceptible
Royal Kidney	1939	heavy	0	0	—	—	
Sharp's Express	1939	heavy	—	0	—	—	
Up-to-date	1939	)	0	0	0	10	
	1940	)	0	0	0	0	resistant
	1941	) light	0	0	0	0	
	1942	) and	0	0	0	0	
	1944	) heavy	0	0	0	10	
	1945	)	0	—	0	—	
White City	1939	heavy	—	—	—	0	highly resistant

Varieties

Of the potato varieties tested, Up-to-date and Arran Banner are those principally grown in Palestine. Epicure, Gladstone, Invincible, Kerr's Pink, Majestic, Alpha, Arran Pilot, and Red Skin are grown to a lesser extent. All the other varieties mentioned in table I are not commonly grown in this country, and the observations recorded here were made on the occasion of a variety trial in 1939. To compare varietal susceptibilities, only big tubers were examined, as these appeared most liable to internal rust spot. (cf. below).

The varieties tested differed widely in their susceptibility to internal rust spot. The varieties Arran Chief, Arran Consul, British Queen, Inverness Favourite, Konsuragis, and White City failed to show disease symptoms even at the latest date of lifting, in July; this level of varietal resistance has been designated as highly resistant in our table. The early varieties: Arran Crest, Arran Pilot, Bintje, Eclipse, Royal Kidney, and Sharp's Express likewise failed to be affected, but as these varieties were grown only in one year and were then lifted early (April to mid-June), this may have enabled them to escape the disease. Up-to-date, Benlomond, Epicure, and perhaps Majestic, were only slightly affected — not more than 20% (Majestic) — even when lifted in July; these varieties have been designated as resistant. The varieties Arran Banner, Kerr's Pink and Red Skin were more severely affected (20-80%), showing a considerable amount of rust spot where the yield was examined in June, and have been marked as susceptible. The most susceptible varieties, which we have referred to as highly susceptible, are Invincible and Champion. Invicible was found affected even in crops lifted as early as end of May or the beginning of June.

Size of tubers

Larger sized tubers generally appeared to be more severely affected by internal rust spot than smaller tubers. To substantiate this impression the yield of six Arran Banner crops, sown in March-April 1939, 1940, 1941 and 1945 in various localities, was graded with regard to both size and incidence of disease. The average percentage of large tubers affected was found to be 63, ranging from a maximum of 100 to a minimum of 43%; of the medium sized tubers an average of 29% was affected (ranging from 50 to 0%) and of the small tubers only 7.5%. Similar gradings of three crops of Invincible showed that with this variety large and medium sized tubers did not differ so markedly in the severity of rust spot, yielding 52 and 51% of affected tubers, respectively, while 17% of the small tubers were affected.

EXPERIMENTS TO DETERMINE THE TRANSMISSIBILITY OF INTERNAL RUST SPOT

Experiments to determine whether or not internal rust spot may be transmitted through affected seed tubers were carried out on the most susceptible varieties: Arran Banner and Invincible. For this purpose mature, large and medium-sized tubers from overhead irrigated crops lifted in summer and found to be affected, were stored in the laboratory in small sacks. Three days before sowing they were graded into three groups of different disease severity, and each of these groups was sown separately. Details and results of these experiments appear in table II.

TABLE II.

The transmissibility of Internal Rust Spot through seed tubers

Variety	*Severity of disease on seed tubers*	*Date of sowing*	*Date of lifting*	*Percentage of yield tubers affected*
Arran Banner	severe	22.12.1939	16. 4.1940	0
	unaffected			0
	severe	15. 9.1940	20.12.1940	0
	light			0
	light	22.11.1940	30. 3.1941	0
	severe			0
	severe	17. 2.1941	9. 6.1941	10.4
	light			1.4
	unaffected			3.4
	severe	14. 1.1942	30. 5.1942	0
	unaffected			0
Invincible	severe	28. 8. and 9. 9.1941	2.12.1941 and 6. 1.1942	0
	moderate			0
	severe	14. 1.1942	27. 5.1942	51
	light			48
	unaffected			44
	severe	5. 3.1942	30. 6.1942	44
	light			49
	unaffected			39
	severe	14. 4.1942	30. 6.1942	26
	light			60
	unaffected			40

The data in the table show that the severity of internal rust spot in seed tubers of Arran Banner and Invincible is not related to the incidence of the disease in the yield tubers. Where conditions did not favour the disease, i.e. in autumn and winter crops, no diseased tubers were found in the yield even where the seed tubers were severely affected. Conversely, where conditions favoured the disease, there was no consistent difference in the severity of internal rust spot in potatoes grown from affected and from sound seed tubers.

SUMMARY

Internal rust spots of potato tubers were investigated over 5 years. The macroscopical and microscopical symptoms of this condition are described.

A survey of the occurrence of internal rust spot in Palestine has established (a) that the condition obtains both on light and heavy soils; (b) that the disease is absent in crops lifted in winter, rare in those lifted in early spring, but increasingly serious in later spring crops, especially when lifted late in summer (July); (c) that potato varieties differ very markedly in their susceptibility to internal rust spot. Of 24 varieties covered by the survey, Invincible and Champion were most susceptible, followed by Arran Banner, Kerr's Pink, and Red Skin. Up-to-date, Majestic, Epicure and some other varieties were affected only slightly and when lifted very late, while many varieties were not affected even then.

In the varieties Arran Banner and Invincible, small tubers were less affected than larger ones. In the case of Arran Banner, medium sized tubers were, in their turn, less affected than large tubers, but with Invincible there was no such difference between these two size groups.

It has been established by experiments that internal rust spot is not transmissible to the yield through affected seed tubers.

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THE INOCULATION OF RYE WITH *CLAVICEPS PURPUREA* AS RELATED TO ENVIRONMENTAL CONDITIONS

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Continuing the work reported in an earlier note (1), the inoculation of rye with *Claviceps purpurea* was further investigated in field experiments from 1941 to 1945. The fact that the inoculations succeeded in some of these years, while they failed in others, prompted us to analyze the meteorological conditions that may have been responsible.

INOCULATION EXPERIMENTS

1. *Production of ergots by inoculation*

Methods. — Rye was grown on light soil at Rehovot, and was irrigated before and after inoculation; a suspension of conidia in water was applied by means of a brush to the flowers. Half the number of inoculated ears was enclosed in paper bags containing moist pieces of cotton wool, the remaining ears remained unprotected.

TABLE I.

Results of inoculations of rye with C. purpurea

Year	Date of inoculation	bagged ears			unprotected ears			all ears		
		No. inoculated	No. infected	% infection	No. inoculated	No. infected	% infection	No. inoculated	No. infected	% infection
1940	14th May	10	1	10				10	1	10
1941	28th April	40	8	20				40	8	20
1942	16th June	25	16	64	25	13	52	50	29	58
1943	13th May	25	18	72	25	15	60	50	33	66
1944	13th April	40	30	75	40	23	56	80	53	66*)
1945	16th April	25	0	0	25	0	0	50	0	0
	25th April	40	0	0	40	0	0	80	0	0
	3rd May	10	6	60	20	4	40	20	10	50

*) Of a total of 1370 ears in the 1944 plot, 315 were found to be infected at the end of the experiment. Secondary infection had evidently taken place.

RESULTS. — The figures presented in table I show that inoculation succeeded to some extent in all except the first two experiments in 1945. The percentage of successful inoculations was only slightly higher in the bagged than in the unprotected ears.

2. *Secondary infections*

In the 1944 experiment 315 out of a total of 1370 ears were infected by *C. purpurea,* although of these only 53 had been inoculated. The number of sclerotia per ear was up to 30. In this year a small beetle of the family *Alleculidae,* which was identified as *Cteniopus gibbosus* Bdi. was prevalent while the rye was flowering. This beetle may have been instrumental in spreading the honey dew appearing on inoculated ears to ears not inoculated. Although LEWIS (6) does not attach much importance to insects as agents of ergot spread "if the rye blooms and ripens evenly over the whole field", yet under the conditions of our 1944 experiment when the period of blooming lasted for about two weeks, the above insects may have played a major part in spreading the ergot.

No ergot infections have been recorded throughout the years of the experiments anywhere in Palestine, not even in the rye fields maintained on an experimental farm some 4-5 km distant from our plots. The above infections were therefore not the result of the natural spreading of the fungus, but were almost certainly indirectly produced by our inoculations.

ENVIRONMENTAL CONDITIONS CONDUCIVE TO INFECTION

1. *Review of literature*

A review of the literature shows that the following temperature relationships have been established for *C. purpurea* in the laboratory: the optimum for growth is generally fixed between 20 and 30°C (2, 3, 8), while temperatures below 10°C and above 37°C are unfavourable (8). According to WLADIMIRSKY (10), the temperature (mean for 24 hours) in those parts of Russia in which the disease is widespread averages 15-20°C.

No laboratory data are available concerning the effect of humidity on *C. purpurea.* In the field, high humidity is generally considered necessary, and rainy summers following upon hard winters are favourable. WENIGER (9), basing herself on the work of various other authors, concludes that a humid atmosphere hastens primary and secondary infections, which are rare in dry periods. Quoting rainfall tables for four years, she shows that ergot was very common in rainy periods, but scarce in periods of low rainfall.— According to MARKHASSEVA (7), ergot infections were not numerous in the Kiev region in 1935 owing to high temperatures and low atmospheric humidities.— HYNES (4) states that infection succeeds in cooler regions, especially when there is fog, and recommends the artificial production of ergots

only for humid climates.— WLADIMIRSKY (10) found only few cases of ergots in certain parts of Russia in which mean (daily?) atmospheric humidity is below 55-69%, while the disease was most widespread where the mean was above 70%.— LEWIS (6) observed that rain falling during the period of infection may be unfavourable for the latter by washing away the spores, and that bright and clear days are those most favourable for infection.

Most of the above mentioned observations show that high humidity favours the infection of rye by ergot. This is further supported by the geographical distribution of the disease, which covers only northerly and west-mediterranean countries, but not dry climatic zones.

2. *Analysis of temperature and humidity conditions in our experiments*

Table II presents data characterising the conditions prevailing during the nights and days of our experiments from 1940 to 1945, indicating the nightly means of relative humidity and temperature, and the day-time minimum of humidity and maximum of temperature.

Relative humidity

During the three days preceding inoculation, relative humidity often fell very low, with nightly means as low as 17% and daily minima of 8-9%, without any apparent effect on the success of inoculations.

On the day of inoculation and the following night, humidities were always fairly high, viz. 80-96% at night, with daily minima of 40-52%; only in 1941 and 1942 was the daily minimum on that day as low as 25 and 32%, respectively, but inoculations were nevertheless successful.

On the day following inoculation, the nightly mean was always above 83% relative humidity, and the daily minimum above 35%.

On the second day after inoculation, and on the subsequent 8 days, humidity at night was generally high and daily minima between 30 and 40%, both in those periods in which inoculations succeeded and in those in which they failed. There were occasional exceptions, with lower nightly means and minima, but never for more than 2-3 days running. We may conclude that under these conditions, though high humidity is considered essential for the development of *C. purpurea,* the level of relative humidity was not the factor responsible for the success of inoculations in some years and its failure in others, as it was almost uniformly high at night-time during all the years.

Temperature

In the five successful inoculation experiments in 1940-1944, the nightly mean temperature on the days preceding and following inoculation and on the day of inoculation itself was, with very rare

TABLE II

Humidity and temperature conditions preceding and following inoculation of rye with ergot, 1940—1945

Day of Observation	11.5—24.5.1940 inoculation successful				25.4—8.5.1941 inoculation successful				3.6—16.6.1942 inoculation successful				10.5—23.5.1943 inoculation successful				10.4—23.4.1944 inoculation successful				13.4—26.4.1945 inoculation failed				23.4—6.5.1945 inoculation failed				1.5—14.5.1945 inoculation successful			
	% Rel. Humid.		Temp. °C		% Rel. Humid.		Temp. °C		% Rel. Humid.		Temp. °C		% Rel. Humid.		Temp. °C		% Rel. Humid.		Temp. °C		% Rel. Humid.		Temp. °C		% Rel. Humid.		Temp. °C		Rel. Humid.		Temp. °C	
	nightly *) mean	minimum	nightly mean	maximum	nightly mean	minimum	nightly mean	maximum	nightly mean	minimum	nightly mean	maximum	nightly mean	minimum	nightly mean	maximum	nightly mean	minimum	nightly mean	maximum	nightly mean	minimum	nightly mean	maximum	nightly mean	minimum	nightly mean	maximum	nightly mean	minimum	nightly mean	maximum
Before inoculation																																
3rd day	86	46	14	25	95	53	12	23	45	22	23	33	88	42	15	26	90	35	12	24	80	40	11	21	62	20	13	26	87	40	12	25
2nd day	18	9	31	37	84	41	15	26	28	14	25	37	90	50	15	25	69	16	18	32	88	43	11	22	38	8	15	31	82	50	13	24
1st day	95	12	17	27	34	14	22	37	63	9	24	42	82	37	15	25	91	47	14	23	86	30	11	25	57	17	15	29	89	40	15	29
Inoculation day	90	52	15	25	96	25	17	24	82	32	19	29	87	46	14	25	92	55	13	22	90	40	11	23	80	45	11	23	91	40	15	29
After inoculation																																
1st day	83	35	15	26	95	42	16	27	88	46	20	28	86	41	14	26	84	39	12	24	89	43	12	23	85	37	9	23	90	30	14	29
2nd day	31	20	23	30	86	47	15	27	92	43		29	61	26	16	28	77	16	17	31	87	54	11	23	66	22	10	25	80	30	14	29
3rd day	30	13	28	41	93	26	14	25	91	55	20	29	88	20	17	32		53		22	79	26	10	23	64	20	12	28	61	10	15	32
4th day	77	12	21	42	87	25	17	28	92	35	21	31	80	39	17	27				22	82	37		22	72	8	15	31	51	13	21	38
5th day	96	51	18	27	75	37	17	30	90	28	20	32	82	32	19	29	83	44	14	23	80	37	13	21	87	40	12	25	62	22	19	35
6th day	90	34	17	26	71	35	17	32	93	56	20	30	92	49	17	28	78	24	14	26	70	30	11	21	82	50	13	24	81	24	19	32
7th day	95	36	16	27	72	29	18	31	51	54	19	29	88	41	16	26	70	25	15	29	62	20	13	26	89	40	15	29	60	28	24	32
8th day	56	25	17	30	27	14	26	36	93	40	20	31	87	44	16	27	88	35	16	29	38	8	15	31	91	40	15	29	80	28	20	34
9th day	92	17	16	30	96	20	17	33	94	51	22	31	89	41	16	27	40	22	19	34	57	17	15	29	90	30	14	29	85	45	19	28
10th day	90	24	16	28	82	22	17	29	94	39	21	32	84	42	15	27	31	10	19	35	80	45	11	23	80	30	14	29				29
Mean for 10 days after inoculation**)	74		16.3		75		16		78		20		84		16.3		74		14		76		11.7		73		12.5		75		17.2	

*) All nightly means calculated for the 10-hour period 8 p.m.—6 a.m.

**) Only the mean temperatures of nights with mean relative humidities above 80% taken into account.

exceptions, always 15°C or in some cases considerably more. In 1945, on the other hand, the nightly mean temperature during the two periods of unsuccessful inoculation was usually between 11 and 14°C, sometimes rising to 15°C but never above that. During the third period of 1945, when inoculation succeeded, nightly means were again higher.

As regards the daily maximum temperature, this on the day of inoculation and on the following day never rose above 30°C. On subsequent days maxima sometimes rose as high as 37°C, and once up to 42°C, but this did not interfere with successful inoculation.

DISCUSSION AND CONCLUSIONS

As we have seen, the general consensus of opinion of authors abroad is that high humidity favours the infection of rye by ergot (7, 9, 10). In that event the humidity prevailing in day-time in Palestine during the season in which rye flowers (mostly minima of 25-50%) must be considered inadequate for that purpose. On the other hand, relative humidities above 80% are then frequent during the hours of the night, and this is when infection must be imagined to take place. But it is worthy of note that infection was also effected where the sequence of nights with high relative humidities was interrupted by 2-3 drier nights, even where this happened only 2 days after inoculation (1940 and third period of 1945).

If the high humidity of the night is a prerequisite to infection, then the level of temperature during the dry hours of the day becomes irrelevant except where it may rise to extremes interfering with the nightly inoculation process. But even the highest temperatures recorded in our experiments — and this included in 1940 two consecutive days with maxima of 41-42°C — failed to prevent infection.

There remain to be considered the temperatures during the night. Here again, only the temperatures of nights with adequate relative humidities need interest us, and in table II we have shown in the bottom line the average nightly mean temperatures for those nights following inoculation in which relative humidity exceeded 80%. It is at once evident that this average amounted to 14-20°C in the years 1940-1944, when inoculations succeeded; but in 1945 inoculations failed while this average temperature was only 11.7-12.8°C, and they succeeded as soon as the average rose higher, to 17.2°C. We may add that in 1944 the average of nightly mean temperatures during the period in which secondary infections took place was also well above 15°C.

We may thus conclude that in the dry spring climate of Palestine infection of rye flowers by *Claviceps purpurea* occurs in nights with adequate humidity. In such nights the level of temperatures is of decisive importance: Where temperatures are as low as 11-12°C, approaching the minimum temperature of growth for *C. purpurea* as determined in the laboratory (8), the limited hours of high humidity

during the night are evidently not sufficient to facilitate infection. However, where mean temperatures are higher, perhaps from 14°C upwards, the fungus appears to be able to establish itself in the course of one or more nights, and infection succeeds.

In cooler climates, in which the flowering period of rye coincides with rain and mist, the position is, of course, quite different. There the nights are probably too cold to make infection possible, but the day-time temperatures of humid days provide the fungus with suitable conditions for its development.

The results of our experiments agree with the opinion expressed by LEWIS (6), that infection of rye by ergot does not depend on rain. In his experiments infections occurred on bright days, and the same happened in our experiments. The level of relative humidity, rather than rain, appears to be the factor decisively affecting infection.

Although it has been evident in our 1944 experiment that the artificial introduction of inoculum into a field in spring may give rise to secondary infections, no natural ergot infections have ever been observed on rye in Palestine.

SUMMARY

Inoculation experiments on rye with *Claviceps purpurea* were carried out 8 times in 6 years. Inoculation succeeded in 6 and failed in 2 experiments. Bagging the ears had little effect on the result of inoculations. Secondary infection of ears not inoculated occurred in one year.

In Palestine infection of rye with ergot can take place only at night, as the hours of the day are too dry. Granted the necessary humidity at night, the success of infections is concluded to depend on temperature, succeeding at nightly means exceeding about 15°C and failing at lower temperatures. High temperatures during the day (up to 42°C daily maximum) and even 2—3 consecutive dry khamsin days and nights following 2 days after inoculation did not prevent the success of the latter.

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SPRAYING AND DUSTING TRIALS FOR TOMATO DISEASE CONTROL

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I. INTRODUCTION

Following our earlier work on the control of tomato diseases in Palestine, the trials described here were designed to evolve a disease control programme suited to each of two important local centres of tomato growing: The Upper Galilee and the so-called "Inner Valleys", i.e. the Eastern part of the Valley of Esdraelon, the Beisan Valley, and the northern Jordan Valley. The Upper Galilee, which has only during the past decade begun to be settled by a network of settlements, has already assumed a leading rôle in the production of summer tomatoes; this may certainly be connected to some extent with the level of night temperatures which in summer are rather lower here than in the remaining centres of vegetable growing in Palestine. In the Inner Valleys, on the other hand, the favourite season for tomato planting is the autumn, when the heat of summer decreases. Here our attention focussed on the late autumn (October) plantings which yield their fruit mainly in spring. This long growing period, which covers the whole of the rainy season, is often curtailed by epiphytotics of leaf and fruit diseases; the latter, in fact, constitute so grave a hazard to the crop, that they may well be considered a limiting factor in its production. Basing on earlier observations our trials in the Upper Galilee wer mainly aimed at the control of powdery mildew [*Leveillula* (*Oidiopsis*) *taurica* (Lev.) Arn.] and of *Alternaria* leaf blight. In the Valleys our aim was chiefly to protect all parts of the tomato shoot from the attack of *Phytophthora infestans* (Mont.)

de By. and of *Alternaria* blight. The species of *Alternaria* dealt with in these trials has not been identified, and several species may well be concerned. In addition to the above diseases, bacterial blight (*Xanthomonas vesicatoria*) appeared in one of the trials and we thus had occasion to examine the effect of various treatments on this disease.

Favourable results obtained in some earlier trials (8) by the addition of oil to copper sprays, indicating the reduction of copper injury to tomato foliage where the oil was added, have prompted us to include some combined copper-oil treatments in some of the trials summarized here.

II. MATERIALS AND METHODS

The Marmande tomato variety was used in all trials.

Irrigation was by furrows in all trials with the exception of trial No. 5 where overhead irrigation was applied.

The plants were planted out 30—40 cm. apart in rows 1.25 m. apart. In all the trials plants were trained on cordons, as is the usual practice in the Jewish settlements in Palestine.

Power sprayers of 2.5—3 HP, working at a pressure of 20—25 atmospheres, were used in all trials, the spray being applied after the morning dew had dried. Dusts were applied with knapsack dusters.

Each treatments was tested on 4 replicate plots, the size of which varied and is indicated below for each trial separately. At least one "barrier" row separated each treatment plot from its neighbour, to prevent drift effects.

Materials

The materials tested were:

(1) Yellow ground sulphur.

(2) Gaza sulphur Superfine grade: ground sulphur from local quarries, containing 90% sulphur; 75% of the dust passes sieve No. 300.

(3) Cita Lime-Sulphur Spray — a lime-sulphur spray of 30—32° Baumé, produced by Messrs. Chemical Industries, Tel Aviv.

(4) Spersul, a proprietary dispersible sulphur preparation for spraying, stated to contain 73% of sulphur. Produced by Plant Protection Ltd., London, and distributed by Imperial Chemical Industries (Levant) Ltd., Tel Aviv.

(5) Floridan, a proprietary spray containing about 8% of metallic copper in ammoniacal solution, with an alkaline reaction. Produced by Messrs. Tapazol, Rishon-le-Tsion, Palestine.

(6) Perenox, a proprietary spray based on cuprous oxide, containing not less than 50% metallic copper and 8% chlorine, with a slightly acid reaction. Produced by Plant Protection Ltd., London, and distributed by Imperial Chemical Industries (Levant) Ltd., Tel Aviv.

(7) Cuprogreen Concentrated, a proprietary spray based on copper oxychloride, containing approximately 50% metallic copper, and neutral in reaction. A product of Belgium.

(8) White Oil (light-medium), containing, according to makers' specifications, 80% oil, 55% distilling over at 636°F, and with 94% unsulphonated residue. Produced by Messrs. Shell Company of Palestine.

(9) Alboleum No. 1 spray oil, produced by Plant Protection Ltd., London, and distributed by Imperial Chemical Industries (Levant) Ltd., Tel Aviv. Specifications of this oil were not available.

Methods of estimation

The incidence of the various diseases on the leaves of treated and untreated plants was estimated by the method outlined in an earlier paper (8), i.e. 6 categories of disease development were distinguished and these were given 0, 0.1, 1.0, 2.0, 4.0 and 8.0 marks, respectively. Entire plots served as units of estimation. Results of estimations on treatment plots were expressed as percentages of the average number of marks of the untreated control plots.

Statistical analysis of yield data followed Saunders' method (10). Significant differences were calculated to a level of 1:20 (P=0.05).

III. TRIALS ON SUMMER AND AUTUMN TOMATOES IN THE UPPER GALILEE

The primary aim of these trials was the control of powdery mildew, which usually appears 4—6 weeks after planting, and of *Alternaria* blight, which develops in the later autumn months. Sulphur fungicides against the former, and combined sulphur and copper treatments against both these diseases were accordingly tested.

Trial No. 1, *Ayelet Hashahar,* 1942. Medium soil. Treatments began two days after powdery mildew was first recorded, and were applied 9 times. To prevent early losses from powdery mildew attack, the plots scheduled to receive copper treatments were sprayed with Cita Lime-Sulphur Spray 1.5% at the first three applications, and thereafter received the scheduled treatments. The incidence of diseases was estimated on 11th December 1942. Each replicate plot measured 50 sq. metres.

Trial No. 2, *Amir,* 1943. Heavy soil. Treatments began two weeks after the first record of powdery mildew and were applied 11 times at intervals of 6—8 days. The plots of treatment No. 4 first received 4 applications of Cita Lime-Sulphur Spray, followed after appearance of *Alternaria* by alternating treatments with this spray and Bordeaux mixture. The incidence of disease was estimated on 9th December 1943. Each replicate plot measured 64 sq. metres.

Trial No. 3, *Amir,* 1944. Heavy soil. Treatments began 10 days after powdery mildew was first recorded. Protracted periods of rain did not permit treatments to be applied on schedule. A total of 10 applications was made, usually at 6—8 days' intervals, but on two occasions 24 and 14 days, respectively, elapsed between successive treatments. Beginning on 23rd November, when *Alternaria* was found to spread rapidly, the plots under treatment No. 2 were also sprayed with Bordeaux mixture, and those under treatment No. 3 were always sprayed with Bordeaux mixture + Spersul and not alternately with this spray and Spersul alone. The incidence of powdery mildew was estimated on 22nd October, that of *Alternaria* on 14th December 1944. Each replicate plot measured 61 sq. metres.

Trial No. 4, Dan, 1944. Medium soil. Application of treatments began before any symptoms of disease were apparent, a total of 11 applications being made at intervals of 6—8 days. Incidence of powdery mildew was estimated on 10th October 1944. Each replicate plot measured 63 sq. metres.

Fusarium root rot appeared on the plots in September. By the end of October this rot had spread so widely that the trial had to be discontinued and no yield records were taken.

Trial No. 5, Eilon, 1944. Heavy soil, overhead irrigation. As the trial was carried out on terraced slopes, the length of rows was not quite uniform and yields were calculated in kg. per metre row. Each replicate plot measured about 70 sq. metres. Spraying began only three weeks after powdery mildew first appeared, and by that time the lower leaves on all plots were already much affected by this disease. A total of 12 applications was made at weekly intervals. Early in November the plants were affected by leaf spots partly due to *Alternaria* and *Septoria lycopersici* and partly to a cause not yet identified. The incidence of diseases was estimated on 11th September 1944. At later estimations the various causes concerned in bringing about the desiccation of leaves could no longer be distinguished.

Further details concerning trials Nos. 1—5, such as growing period, dates of disease appearance and nature of treatments tested, are presented in table I together with the results.

RESULTS

In all these trials the incidence of powdery mildew on the control plots was severe. All the sulphur fungicides effectively checked the disease, and dusting with yellow sulphur or Gaza sulphur Superfine grade and spraying with Cita Lime-Sulphur spray 1.5% or Spersul 1% was equally effective. Spersul was in several trials added to Bordeaux mixture, Perenox, or Floridan without losing any of its efficacy in controlling the powdery mildew.

As regards the control of *Alternaria* blight, the efficacy of the copper treatments was outstanding wherever this disease appeared. While sulphur treatments, such as sulphur dust or lime-sulphur spray, also reduced the incidence of this blight to some extent, the effect of Bordeaux mixture 0.75%, Perenox 0.25% and Floridan 1.25% (to all of which Spersul was added), was always superior to that of sulphur fungicides.

In the first three trials the fungicidal treatments markedly increased the size of the yield by about 20 to 50% above the control yield, the difference being significant in most cases. In trial No. 5 the general level of yields was so high that even the most successful treatments did not raise it by more than 13% above the control yield. Differences between the yields obtained by different treatments were not significant in any of these trials. This agrees with the fact that the degree of powdery mildew control was fairly uniform on all treatment plots, but does not reflect the marked differences in blight control which were observed in three trials.

TABLE I

The effect of fungicidal treatments on the incidence of powdery mildew and Alternaria blight and on the size and distribution of yield in trials on summer and autumn tomatoes in the Upper Galilee

Date of first record of powdery mildew	Date of first record of Alternaria blight	Treatment	Incidence of diseases (control = 100%) powdery mildew	Incidence of diseases (control = 100%) Alternaria blight	Size of yields (mean) in kg. per plot	Size of yields (mean) in kg. per dunum	Size of yields (mean) %	% late yield (total yield per treatment = 100%)
		Trial No. 1, Ayelet Hashahar, 25.8.1942—13.1.1943						
		1) Control	100 (4 marks)	100 (4 marks)	107	2140	100	13.9
		2) Gaza sulphur Superfine	23	35	163	3260	152	34.0
20.9.	25.10.	3) Cita Lime-Sulphur 1.5%	30	33	129	2580	120	36.9
		4) As in 3); after appearance of Alternaria-Perenox 0.25%	25	18	137	2740	128	24.2
		5) As in 3); after appearance of Alternaria-Perenox 0.25% + Alboleum 1%	25	25	131	2620	122	30.9
		significant differences:			48.7	974	45.5	8.59
		Trial No. 2, Amir, 20.7.1943—29.1.1944						
		1) Control	100 (6.6 marks)	—	182	2730	100	8.5
		2) Gaza sulphur Superfine	41	—	247	3710	136	26.6
13.9.	—	3) Cita Lime-Sulphur 1.5%	38	—	272	4090	149	31.7
		4) Cita Lime-Sulphur 1.5% alternating with Bordeaux mixture 0.75%	35	—	264	3960	145	31.8
		significant differences:			36.8	551	20.2	22.66
		Trial No. 3, Amir, 25.7.1944—20.1.1945						
		1) Control	100 (4.6 marks)	100 (6.3 marks)	197	1650	100	5.7
5.9.	20.10.	2) Cita Lime-Sulphur 1.5%	37	55	233	1950	119	11.8
		3) Bordeaux mixture 0.75% + Spersul 1% alternating with Spersul 1%	37	16	264	2200	133	19.1
		significant differences:			34.7	288	17.6	6.33
		Trial No. 4, Dan, 20.6.—15.11.1944						
		1) Control	100 (3.9 marks	—	—	—	—	—
		2) Yellow sulphur	10	—	—	—	—	—
25.8.	—	3) Cita Lime-Sulphur 1.5%	18	—	—	—	—	—
		4) Spersul 1%	15	—	—	—	—	—
		5) Perenox 0.25% + Spersul 1%	13	—	—	—	—	—
		6) Perenox 0.25% + Spersul 1% + white oil 1%	21	—	—	—	—	—

Date of first record of		Treatment	Incidence of diseases (control=100%)		Size of yields (mean)			% late yield (total yield per treatment
					in kg.		%	
Powdery mildew	Alternaria blight		powdery mildew	Alternaria blight	per plot	per dunum		
Trial No. 5, *Eilon*, 9.6.—1.12.1944								
		1) Control	100 (4.0 marks)	100*) (6.8 marks)	14.7	6100	100	5.8
25.7.	5.11.	2) Cita Lime-Sulphur 1.5%	56	58	16.6	6900	113	23.8
		3) Perenox 0.25% + Spersul 1%	44	26	16.7	6950	114	30.4
		4) Floridan 1.25% + Spersul 1%	69	25	16.8	7000	114	35.5
		5) Cita Lime-Sulphur 1.5% alternating with Perenox 0.25% + Spersul 1%	56	38	15.4	6400	105	32.2
		significant differences:			3.04	1265	20.7	15.09

The percentage of late yield was increased by all the fungicidal treatments in all these trials, and the increase was mostly significant as compared with the controls. In trials Nos. 3 and 5 the percentage of late yield on the plots treated with copper sprays exceeded that obtained on the plots receiving sulphur treatments only, and the level of late yield was seen to bear an inverse relationship to the incidence of *Alternaria* blight. No such relationship was apparent in trial No. 2, but this may be due to the adverse conditions with which the plots of this trial had to contend at the end of the growing period.

The addition of oil — in trial No. 1 Alboleum No. 1 and in trial No. 4 light-medium Shell oil, both at 1% strength — failed to affect the action of Perenox on powdery mildew and *Alternaria* blight. No increase in yield could be observed in trial No. 1 on the plots treated with Alboleum and Perenox as compared with those sprayed with Perenox alone.

IV. TRIALS ON AUTUMN AND WINTER TOMATOES IN THE INNER VALLEYS

As these trials were mainly designed for the control of *Phytophthora* and *Alternaria* blights they comprised in the main copper treatments. However, in view of some earlier indications that sulphur fungicides may also have some effect on *Alternaria*, and considering the importance of sulphur in controlling powdery mildew, sulphur treatments were included in two of the trials.

*)In addition to *Alternaria* blight, symptoms of *Septoria lycopersici* and leaf spots due to an undetermined cause were also observed on the plants in trial No. 5.

Trial No. 6, Tel Amal, 1942/43.

Planted 9th September 1942 on chalky soil. Treatments applied 8 times at 6—8 days' intervals between 30th November and 22nd January 1943. Each plot measured 63 sq. metres.

The only disease assuming serious proportions was the bacterial spot caused by *Xanthomonas vesicatoria.* This disease first appeared on both leaves and fruits in late November and developed rapidly. The incidence of this disease on each plot was estimated on 22nd December 1942 on samples of 50 leaves, which were assigned marks ranging from 0.1 to 4.0.

TABLE II

The effects of treatments on the incidence of Xanthomonas vesicatoria and on the size of yield (trial No. 6)

Treatment	Incidence of disease		Size of Yield		
	on leaves	on fruits (No. of affected fruits divided by total weight of yield)	per plant	per dunum	%
1) Control	100 (0.9 marks)	1.20	1.29	2100	100
2) Gaza sulphur Superfine	105	1.10	1.42	2325	111
3) Cita Lime-Sulphur 1.5%	110	1.11	1.28	2090	99
4) Bordeaux mixture 0.75%	99	1.33	1.26	2060	98
5) Cuprogreen Conc. 0.5%	102	1.26	1.34	2190	104
6) Perenox 0.25%	88	1.35	1.23	2010	96
7) Perenox 0.25%+white oil 1%	99	1.10	1.33	2180	104
significant differences:		0.383	0.347	570	27.0

Results. None of the treatments tested reduced to any considerable extent the incidence of *Xanthomonas vesicatoria* on either leaves or fruits. The slight differences in the incidence of disease on some of the plots was not reflected in the yield data, and all plots yielded closely similar weights of fruit.

Trial No. 7, Tirat Tsvi, 1943/44.

Planted late September 1943 on medium soil. Each plot measured 50 sq. metres. Commencing before appearance of any disease symptoms, treatments were applied 17 times between 10th January and 26th May 1944. During the first two months, treatments were applied aproximately once in 16 days, thereafter once in 10 days. All further details appear in table III.

Results. Leaf diseases. After rapid development of both *Phytophthora* and *Alternaria* blight during the month of January, it was not possible to distinguish with certainty between the effects of these two blights, especially as far as the drying up of leaves was concerned. At the first estimation, on 8th February, both diseases were therefore estimated together, though *Phytophthora* blight seemed to be predominant. Blight incidence on the control plots was by then moderate to severe. Bordeaux mixture and Perenox reduced blight by about two thirds, sulphur dust and Bordeaux mixture + oil by about one half, while Floridan was less effective. *Phytophthora* then

ceased to develop, and on 20th March we estimated the incidence of *Alternaria* on the growth that survived the winter months. Thereafter fresh spring growth was made and, on 10th May, the incidence of this blight on the new foliage was estimated. On both occasions *Alternaria* was moderately severe in the controls, slight or very slight on the plots sprayed with Bordeaux mixture (with or without oil) or Perenox.

The blight was slightly more prominent on plots under Floridan treatment, and much more so where only sulphur was applied. Bordeaux mixture caused the leaves to harden, but the addition of oil to the spray prevented this effect.

Fruit diseases. Early in May most of the control fruit was found affected by *Alternaria* either on the calyx leaves or on their stem end. Here again sulphuring had little effect, but Bordeaux mixture and Perenox greatly reduced the estimated percentage of affected fruit.

Yield. Yield increases due to the treatments were significant except on the plots treated with sulphur or Floridan. Spraying with Bordeaux mixture gave yields significantly exceeding those of the other treatments (including Bordeaux mixture + oil) with the exception of Perenox.

TABLE III.

The effect of treatments on the incidence of Phytophthora and Alternaria blights on leaves and fruit, and on the size and distribution of yield (trial No. 7)

Treatment	Incidence of leaf diseases (control =100%)			Incidence of Alternaria on fruits (estimated)		Size of Yield in kg.		%	% Yield picked in spring (total yield in each treatment = 100%)
	both blights	Alternaria				per plant	per dunum		
	27.1 - 8.2	20.3.	10.5.	10.5	23.5.				
Control	100 (3 marks)	100 (2.5 marks)	100 (2 marks)	63	100	1.49	1830	100	45.9
Gaza sulphur Superfine	50	53	69	50	93	2.67	3280	179	49.9
Perenox 0.25%	37	28	7	8	63	4.25	5230	285	54.4
Bordeaux mixture 0.75%	34	16	6	3	53	5.68	6990	381	49.8
Bordeaux mixture 0.75% + white oil 1%	51	10	5	3	60	4.14	5090	278	54.0
Floridan 1.25%	70	40	22	21	83	3.00	3690	200	53.6
significant differences :						1.53	1870	102	

Trial No. 8, *Geva, Autumn* 1943.

Planted 22nd September on heavy soil, irrigated by sprinklers. Treatments were applied 6 times at intervals of 6—7 days, beginning before appearance of disease symptoms on 23rd November and ending on 27th December 1943. A severe attack of *Phytophthora* and *Alternaria* developed in December, and early in January the plants suffered low temperature injury though there was no frost. The injury consisted mainly of purple tinting and partial desiccation of the leaves.

Results. The incidence of blights was markedly lower on the plots sprayed once a week with copper (Floridan) than on those alternately receiving this and lime-sulphur spray or those only dusted with sulphur. Similarly, the weekly Floridan spray was much more effective than the other treatments in reducing the extent of low temperature injury. In consequence of this double action, the condition of the plots sprayed weekly with Floridan was much better than that of all other plots when the degree of desiccation was estimated late in January (cf. table IV).

TABLE IV.

The effect of treatments on the incidence of Phytophthora and Alternaria blights and on low temperature injury (trial No. 8)

Treatment	Incidence of blights (control=100%) 18.1.1944	Amount of low temperature injury (control=100%) 18.1.1944	Proportion of dried foliage % 25.1.1944
Control	100 (4.3 marks)	100 (1.8 marks)	75
Yellow sulphur	72	82	56
Cita Lime-sulphur 1.5% alternating with Floridan 1.25%	66	71	50
Floridan 1.25%	45	48	27

Trial No. 9, *Messilot,* 1944/45.

Planted on 20th September on chalky soil. Each plot measured 62 sq. metres. Commencing about 10 days after appearance of the first symptoms of *Alternaria,* treatments were applied 8 times between 1th November 1944 and 25th January 1945. Treatment intervals were mostly 6—8 days but, owing to rain, had to be longer on two occasions. The effect of treatments on the amount of *Alternaria* on the fruit was determined by grading the fruit picked at the end of the season on 7th and 11th February 1945.

Results. As apparent from table V, spraying kith either Bordeaux mixture or Perenox effectively checked the leaf blight due to *Alternaria,* increased the yield significantly by about 70%, and raised the percentage of marketable fruit at the last pickings from almost nil to 50—60%. Spoilage of fruit on the control plots was almost wholly due to *Alternaria.*

TABLE V.

The effect of treatments on the incidence of Alternaria leaf blight, and on the size and grade of yield (trial No. 9)

Treatment	Incidence of Alternaria leaf blight	Size of Yield in kg. per plant	per dunum	%	Grade of fruit picked on 7th and 11th February % grade, A (marketable)	% grade, B (for home use)	% grade C (waste)
Control	100 (4.8 marks)	1.15	1725	100	4.0	50.7	45.3
Bordeaux mixture 0.75%	25	1.97	2950	171	61.8	31.5	6.7
Perenox 0.25%	35	1.92	2875	167	49.2	40.2	10.7
significant differences:		0.271	407	23.6			

V. DISCUSSION

A. *Powdery Mildew*

Our earlier trials (8) have shown how well 1.5% lime-sulphur spray will control powdery mildew of tomatoes. The trials reported here confirm this and indicate that the disease is also satisfactorily controlled by other sulphur fungicides such as various sulphur dusts and the dispersible sulphur spray Spersul. This is of considerable practical significance because (a) sulphur dusting is much cheaper than spraying, and (b) Spersul can be added to copper sprays so that a combined spray is obtained that will control the mildew as well as blights, *Septoria* and other diseases.

B. *Bacterial Blight*

Conflicting claims have been made in literature regarding the effect of fungicides on bacterial blight (*Xanthomonas vesicatoria*). In the United States, HARRISON (5) found that both Bordeaux mixture and some fixed copper sprays controlled the disease, and GARDNER (3) reported its partial control by copper-lime dusts. On the other hand, RUSSELL (9) found in Bermuda that even thorough spraying with Bordeaux mixture failed to control the disease. Our results agree with those of the latter author and show, moreover, that sprays based on cuprous oxide and copper oxychloride and sulphur dust or lime-sulphur spray are, at the concentrations tested, all ineffective against bacterial blight.

C. *Alternaria and Phytophthora Blight*

Bordeaux mixture has long been the standard spray for the control of these blights. The strength most commonly advised abroad is 1% (1, 11, 13), while higher concentrations of 1.5 to 2% are also advocated (2, 4, 6). On the other hand, as weak a concentration as

0.5% has been found effective against both blights in Rhode Island (13) and against *Alternaria* blight alone in Australia (7). Our trials show that in Palestine 0.75% Bordeaux mixture (0.19% metallic copper) will effectively control both *Phytophthora* and *Alternaria* blights of tomatoes.

As regards the effect of other copper compounds, Perenox gave good results against both blights when used at a strength of 0.25% (0.125% Cu). Floridan, used at a concentration of 1.25% which contains 0.10% copper in ammoniacal solution, equalled in one trial the effect of Perenox on *Alternaria*, but in another trial its effect on both the blights was inferior to that of Bordeaux mixture or Perenox.

A certain limited effect on *Alternaria* of sulphur fungicides, whether in form of sulphur dust or of lime-sulphur spray, was noted in five trials, but they never equalled or even approached the action of the copper fungicides.

D. *Low Temperature Injury*

In the only experiment in which the effect of treatments on low temperature injury of tomatoes could be observed, weekly applications of a copper spray (Floridan) resulted in much less injury than in the controls, while sulphur dusting had little effect. As far as we are aware no such effect of copper sprays has hitherto been reported, but the observations presented here agree with the results of an earlier experiment (8), in which we noted the protection from frost injury conferred by copper sprays on tomato fruits.

E. *Phytotoxic effects and the action of oil sprays*

No phytotoxic effects on tomatoes have been observed in these trials as far as the sulphur treatments are concerned, and neither sulphur dust, nor lime-sulphur spray nor Spersul caused scorching.

As regards the copper treatments, Bordeaux mixture (0.75%) was noted in one trial to have caused marked hardening of the leaves, while the other copper treatments failed to do so; nevertheless, the plots sprayed with Bordeaux mixture gave the highest yield in this trial.

Oil amendments were tested in three trials and in no case affected the fungicidal action of the materials they were added to (Bordeaux mixture, Perenox). The addition of oil to Bordeaux mixture prevented the leaf hardening caused by the latter spray in the above mentioned trial, but did not increase the yield. Table VI summarizes the comparative yields obtained by sprays with and without oil in three of the trials described in earlier sections of this paper, and in one further trial carried out in 1942 in the Haifa Bay. The data show that the addition of oil failed to increase yields under any of the widely differing conditions of these trials. It must be emphasized that all these trials were carried out under conditions of ample soil moisture. These results therefore do not necessarily contradict our earlier findings (8) that the addition of oil to copper sprays may prevent the

injury caused by the latter alone when applied to plants growing under drought conditions, and may thereby increase the yield.

TABLE VI

The effect on tomato yield of oil amendments to various fungicidal sprays

Locality and year	Season	Treatment	Size of Yield in kg. per dunum	Size of Yield % (control = 100%)	Significant difference %
Ayelet Hashahar, 1942	autumn	Perenox 0.25%	2740	128	45.5
		do. + Alboleum 1%	2620	122	
Tel Amal, 1942	autumn-winter	Perenox 0.25%	2010	96	27.0
		do. + white oil 1%	2180	104	
Tirat Tsvi, 1943	winter-spring	Bordeaux mixture 0.75%	6990	381	102.0
		do. + white oil 1%	5090	278	
Haifa Bay, 1942	summer	Cita Lime-sulphur 1.5%	3300	100	25.8
		do. + white oil 1%	3220	98	

VI. SUMMARY

Five trials were carried out in 1942-1944 to control the diseases of summer and autumn grown tomatoes in the Upper Galilee, while four trials during the same period aimed at the control of disease on autumn and winter grown tomatoes in the inner valleys of Palestine.

Spraying with lime-sulphur spray (1.5%) or Spersul (1%) gave excellent control of powdery mildew (*Leveillula taurica*). In three trials on tomatoes irrigated by furrows the action of these sprays was equalled by that of sulphur dust.

Alternaria and *Phytophthora* blights of tomato leaves and stalks was satisfactorily controlled by copper treatments, especially by Bordeaux mixture (0.75%) and Perenox (0.25%). These sprays also greatly reduced the incidence of *Alternaria* blight on fruits. The various sulphur treatments tested appeared to have a limited effect on *Alternaria,* but were much inferior to the copper treatments.

Neither the copper nor the sulphur treatments tested succeeded in reducing the incidence of bacterial blight (*Xanthomonas vesicatoria*) on leaves and fruit.

In one trial weekly applications of a copper spray (Floridan) succeeded in reducing the extent of injury caused to tomato foliage by temperatures slightly above the freezing point.

The addition of the dispersible sulphur preparation Spersul to various copper sprays did not affect the efficacy of the latter; the combined treatment is suitable for the simultaneous control of powdery mildew and *Alternaria* blight.

The addition of 1% oil (Alboleum No. 1 or light-medium white oil) to copper sprays did not affect either the efficacy of these sprays

or the resulting yields, in trials in which the plants were adequately supplied with moisture.

In the summer and autumn trials in the Upper Galilee, the control of powdery mildew and *Alternaria* by the combined Spersul-copper treatment resulted in yield increases of 13-33%, or up to 900 kg. per dunum, as compared with the controls. In a trial in which powdery mildew was the only disease present, sulphur dusting or lime-sulphur spraying increased the yield by 36-49% (1000-1300 kg. per dunum).

In the autumn and winter trials in the inner valleys, control of *Phytophthora* and *Alternaria* blights by Bordeaux mixture or Perenox increased the yield to a total of 5.1 tons per dunum. In one case the control of *Alternaria* by these treatments not only raised the yield by 1.2 tons per dunum but also greatly improved its quality.

In the experiments in the Upper Galilee the control of diseases resulted in a marked extension of the picking period.

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FURTHER WORK ON THE APPLICATION OF FUNGICIDAL SPRAYS BY OVERHEAD IRRIGATION EQUIPMENT

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In an earlier paper (2) a description has been given of a series of experiments demonstrating that application of certain fungicides at low pressure through ordinary overhead irrigation pipes may effectively check the development of some major crop diseases. The diseases thus controlled included *Alternaria* blight (*A. solani*) and powdery mildew (*Oidium sp.*) of potatoes and downy mildew (*Pseudoperonospora cubensis*) of cucumbers. The initial success of this method of spraying encouraged us to test its effect in the control of that most destructive of all the diseases attacking potatoes in Palestine, the *Phytophthora* blight (*P. infestans*). This paper is to describe the results of trials to control this blight by the novel method of spraying and of the steps taken to introduce the latter into the agricultural practice of Palestine.

In all this work the spray material used was the cuprous oxide concentrate 'Perenox' (50% Cu), applied at $^1/_3$% strength. The incidence of *Phytophthora* blight was estimated on a scale of 6 categories (0—8 marks), as described elsewhere (1).

SMALL SCALE TRIAL

In this trial overhead application of spray was effected by connecting the outlet pipe of an ordinary 2.5 HP Hardie power sprayer with one end of the irrigation pipe lines. The capacity of the pump with which this sprayer is normally equipped sufficed to supply the spray liquid at the desired pressure (sufficient to spray a belt of 7.5 metres' width on each side of the pipe) to 15 metres' length of pipe bearing 1 mm. nozzles at intervals of 90 cm.

A plot of Up-to-Date potatoes sown in March 1945 on light, poor soil at Mishmar Hasharon (central coastal plain of Palestine) was sprayed 7 times. Applications were made at 6—9 days' intervals, between 17th April and 27th May, first symptoms of *Phytophthora* blight were recorded on 23rd April 1945. The rate of spraying by overhead pipe was estimated at 300—400 litres per dunum (=1000 sq. metres), while about 150 litres per dunum were applied to the plots sprayed by motors sprayer in the ordinary way, through long rubber hoses. Each mode of application was tested on 4 replicate plots, and there were 4 unsprayed controls.

Results

Table I summarizes the results of this trial. The incidence of *Phytophthora* blight on the controls was severe, but the disease was effectively checked by the spray. There was no appreciable difference between the amount of disease on the plots sprayed by overhead pipes and those sprayed in the ordinary fashion. However, a large and highly significant increase of yield was brought about by the former, as compared with the latter mode of spraying. In view of the uniformly slight incidence of blight on all the sprayed plots, this yield increase on the plots sprayed by overhead pipes is not readily explained. It may perhaps be due to a stimulant effect of the relatively large quantities of copper applied by this method to the potatoes growing on the poor, and possibly deficient, soil of this trial.

TABLE I

Effects of treatments on incidence of Phytophthora blight and on the size of yield in a small scale trial

Treatment	Incidence of Phytophthora (control=100%)	Yield in kg. per dunum	Yield % (control=100%)
Control, untreated	100 (4.7 marks)	1350	100
Perenox 1/3%, normally applied	8	1580	117
Perenox 1/3%, overhead application	15	2280	169
significant difference (P=0.05)		347	25.7

FIELD SCALE TRIAL

A self-priming pump capable of delivering 4-5 cubic metres per hour at 3 atmospheres' pressure was coupled to a 3 HP Hardie sprayer. The outlet pipe of the pump was connected with an ordinary "Matar" system comprising a reciprocating water motor coupled to oscillating overhead spray pipes. By this arrangement we were able to effect overhead application of spray to normal, 15 metres wide plots through entire irrigation pipe lines of standard length (65 metres).

A plot of Up-to-Date potatoes sown in March 1946 on heavy soil at Ein Hahoresh (central coastal plain) was sprayed four times, on 29th April, 8th, 14th and 30th May, 1946; first symptoms of *Phytophthora* blight were recorded on 6th May. — Overhead application of spray was tested on two plots, each measuring 65 by 15 metres, two comparable plots were sprayed in the ordinary way by motor sprayer, and two plots served as controls. The rate of spraying through the overhead pipes was 220 litres per dunum, which were applied in the course of 3—4 minutes. — To determine yield effects, the yield on sample plots of 45 sq. metres' size were lifted on each of the experimental plots on 6th July 1946.

Results

Table II presents the results of this trial. The control plots were very severely infected with *Phytophthora*. The spray applied in the ordinary fashion appeared slightly more effective than overhead spraying in controlling the blight; but the yield obtained by either mode of spraying was very similar and almost double as high as in the control plots.

TABLE II

Effect of treatment on incidence of Phytophthora blight and on the size of the yield in a field scale trial.

Treatment	Incidence of Phytophthora (control=100%)	Yield	
		in kg. per dunum	% (control=100%)
Control, untreated	100 (6 marks)	1780	100
Perenox 1/3%, normally applied	21	3450	194
Perenox 1/3%, overhead application	37	3230	182

OVERHEAD SPRAY APPLICATION IN AGRICULTURAL PRACTICE

The method of overhead application of spray described above for the field scale trial has successfully been used by Ein Hahoresh settlement to protect its entire spring potato crop (50 dunums) from blight. The rate of spraying averaged 200—220 litres per dunum.

It was, however, obvious that this method of spraying could be greatly simplified, if the spray liquid could be injected directly into the irrigation pipes. Equipment suitable for this purpose has been devised jointly by Z. Rogowsky B. Sc. (Eng.), of Messrs. I.C.I. (Levant) Ltd., and Messrs. "Matar", Givat Brenner. This equipment may briefly be described as a mains pressure actuated simple injection pump injecting directly into the main water stream. The pressure difference is created by an orifice plate in the streamline and operates a simple plunger pump.

This equipment has been used at Givat Brenner to protect the potato crop in spring 1947. *Phytophthora* blight was absent, but *Alternaria* blight was prevalent and was satisfactorily controlled, the rate of spraying averaging about 200 litres per dunum.

In the light of the experience gained in 1946 and 1947 it can be stated with certainty, that the rate of application of sprays through overhead irrigation equipment need not exceed the ordinary rate of spraying by more than a small margin. There is definitely no need, when using the novel method, to apply spray at rates 2—3 times as high as the normal, as appeared to be the case in our earlier trials(2).

The following points of practical importance have emerged from the use of overhead application of spray to larger areas in two seasons :

(a) As the spray falls on the plants from above only, it may be difficult to cover the lower leaves where the spray is first applied when the potato plants are already fully developed. It is therefore important to make the first application before the growth is so full that the lower leaves can no longer be reached, even if this means advancing the date of the first spray to some extent.

(b) Winds may seriously interfere with spraying. As overhead

irrigation pipes are usually installed on numerous parallel and adjacent plots, this usually affects only the plot outermost towards the direction from which the wind blows. On this plot part of the plants may remain unprotected and will have to be sprayed by ordinary sprayers in order to prevent the formation of blight foci.

(c) Repeated application of Perenox through the irrigation system has no adverse effect on the pipes and the "Matar" oscillator and does not block the nozzles.

(d) A large saving of labour is effected by overhead application, and no motor sprayer, hoses, horses or tractor are required.

(e) Injury to crops by wheels or motor sprayers or by the dragging of hoses is avoided entirely.

(f) From a phytopathological point of view the greatest advantage of overhead spray application is that it facilitates effective timing of the spraying operation, regardless of the condition of the ground etc. With diseases such as *Phytophthora* blight, where timing is extremely important and short delays may be fatal, this fact alone ensures the superiority of overhead spraying.

(g) Owing to the reduced cost, and sometimes the increased efficacy, of spraying by overhead application, this method of spraying may render it possible to use fungicides and insecticides even on crops on which this has not so far been profitable.

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SUMMARY

Application of $^1/_3$% Perenox spray through overhead irrigation equipment has proved effective in checking *Phytophthora* blight of potatoes.

The experiences so far gained in the use of this method of spraying on a larger scale, and its advantages as compared with ordinary spraying methods are briefly discussed.

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CONTROL OF DIPLODIA STEM-END ROT AND MOULDS IN SHAMOUTI ORANGES WITH NITROGEN TRICHLORIDE (DECCO PROCESS)

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I. INTRODUCTION

Nitrogen trichloride gas (NCl_3) has been commercially used in California for more than ten years for the control of wastage in Citrus fruit. This treatment is known as the 'Decco' process. KLOTZ (1), in extensive tests in cooperation with the California Fruit Growers' Exchange, proved its effectiveness in decreasing losses from citrus fruit decay due mainly to *Penicillium digitatum* and *Penicillium italicum*. He also proved that concentrations of 4 to 6 mg. NCl_3 per cb. ft. of air for a period of 30 minutes were lethal to the spores of both the *Penicillia* and further to *Phytophthora citrophthora, Colletotrichum gloeosporioides, Alternaria citri* and *Botryosphaeria ribis*, all of them fungi causing citrus fruit rot. No data were given on the effectiveness of NCl_3 on *Diplodia*, the chief causal agent of stem end rot in Palestine. Outside America a trial, on a small scale only, was carried out in Australia (2). This trial confirmed the efficacy of the gas in controlling moulds, but showed negative results against stem-end rot (*Diplodia*).

Since under Palestinian conditions diplodia stem end rot is very deleterious to Shamouti oranges, and represents one of the main problems of the citrus industry of Palestine, the experiments were therefore chiefly concerned with the efficacy of nitrogen trichloride in controlling stem end rot, but the effects on green and blue mould due to *Penicillium digitatum* and *P. italicum* were also recorded.

Nitrogen trichloride is a gas that is commercially generated from ammonium chloride and chlorine. The empiric equation is:

$$NH_4Cl + 3Cl_2 = 4HCl + NCl_3$$

The gas is used generally in dilutions as low as 7 mg. per cb. ft. of air. The undiluted or concentrated gas is explosive, while dilutions as mentioned above are harmless. The gas must therefore be diluted in the apparatus as soon as it is generated. Being approximately 4 times heavier than air, the gas has to be dispersed by fans into the fumigation room. The solubility of the gas in water is very low.

II. EFFECT OF NITROGEN TRICHLORIDE ON ROTTING

(a) *Experiments with inoculated fruit*

The investigations were carried out to determine the relative effectiveness of nitrogen trichloride in controlling

a) stem end rot of Shamouti oranges, due to *Diplodia natalensis*, and

b) the moulds due to *Penicillium digitatum* and *P. italicum*.

Furthermore, the influence on the efficacy of the gas treatment of wounding, of the time of treatment, and of the time of packing were studied.

Methods

Shamouti oranges were picked from a grove in the neighbourhood of the Agricultural Research Station, Rehovot, on the 28th January 1946, inoculated with the respective organism 2 days later, then subjected to the treatments detailed in tables I-III. The oranges inoculated with the *Penicillia*, were stored at 18°C for 24 days, and examinations of the fruit were made after 10 and 24 days. The oranges inoculated with *Diplodia* were stored at 18°C for 31 days, being examined after 23 and 31 days. The number of fruits in each item was 150-200.

Inoculations with *Diplodia* were made by wetting the button of the fruit with an aqueous spore suspension of the fungus. After drying, a diagonal cut about 1 mm. deep was made from the cut surface into the stalk of the button. The *Penicillia* were inoculated by dipping the fruit into a heavy aqueous spore suspension of each of the fungi. In the case of fruit wounded after inoculation, 6 lateral pricks, 3 on each side, were made with a pin to a depth of about 1.5 mm.

One application only of NCl_3 was made. As the result of preliminary tests of the tolerance of Shamouti oranges to the gas (cf. below) 7 mg. per cb. ft. of air for a period of 6 hours was chosen as standard treatment of NCl_3. Treatments were applied in a tent, the gas being introduced by means of a hose and circulated by fans. The actual concentration of the gas was measured and adjusted at intervals of 45 minutes throughout the period of treatment. Minimum temperatures inside the tent ranged from 12-13°C, maximum temperatures from 18-19°C.

Results

The data presented in table I indicate that nitrogen trichloride treatment effectively reduced the incidence of *Diplodia* stem end rot and of the two *Penicillia*, in wounded as well as non-wounded fruit, provided the gas was not applied immediately after inoculation, but one day later.

There was some indication that the gas treatment was more effective against *Diplodia* on wrapped than on non-wrapped fruit.

TABLE I.

The effect of nitrogen trichloride treatment on rotting of Shamouti oranges inoculated with Diplodia natalensis, Penicillium digitatum, and Penicillium italicum, respectively
(each item 120-180 fruits)

	Control, untreated		Gassed *immediately after* inoculation, non-wrapped, non-packed		Gassed 1 *day after inoculation* non-wrapped, non-packed		wrapped, packed	
	wounded	non-wounded	wounded	non-wounded	wounded	non-wounded	wounded	non-wounded
I. *Oranges inoculated with Diplodia natalensis*								
% rot after 23 days								
stem-end rot	10.8		12.3		4.1		1.3	
Penicillia	15.8		10.0		1.5		0.7	
total rot	26.6		22.3		5.6		2.0	
% rot after 31 days								
stem-end rot	37.5		47.7		10.2		4.7	
Penicillia	15.8		11.5		2.6		0.7	
total rot	53.3		59.2		12.8		5.3	
II. *Oranges inoculated with Penicillium digitatum*								
% rot after 10 days								
P. digitatum*)	40.0	40.0	10.4	g.8	2.2	4 4	5.9	10.0
% rot after 24 days								
P. digitatum	68.3	70.8	31.1	19.2	13.9	9.4	14.1	18.0
P. italicum	0.6	0	3.0	0	2.2	0.6	0	0.7
stem end rot	9.4	6.7	5.2	10.0	1.1	2.8	0	1.3
total rot	78.3	77.5	39.3	29.2	17.2	12 8	14.1	20.0
III. *Oranges inoculated with Penicillium italicum*								
% rot after 10 days								
P. italicum	15.8	7.5	4 5	0.7	2.5	1.2	1.7	4
P. digitatum	0	0	0	0.7	0	0	0	0
stem end rot	0	0	0.	0	0	0	0	0
total rot	15.8	7.5	4.5	1.5	2.5	1.2	1.7	0
% rot after 24 days								
P. italicum	39.2	20.8	37.3	9.0	19.4	4.8	4.4	2.7
P. digitatum	2.5	5.0	6.4	3.7	2.5	0	2.2	1.3
stem end rot	1.7	3.3	8.2	18.7	6.3	1.8	1.7	2.0
total rot	43.3	29.2	51.8	31.3	28.8	6.7	8.3	6.0

*) No other rots were present at this stage.

(b) *Experiments with commercially handled (non-inoculated) fruit*

To determine the value of NCl_3 treatment under commercial conditions, experiments were carried out with fruit known to be naturally infected by *Diplodia* stem end rot. The factors studied with regard to their effect on the efficacy of the gas treatment in controlling orange

decay were: the number and time of treatment applications, the concentration of gas, the time of wrapping and packing, and the storage temperature.

Methods

The experiments covered the 1945/46 and 1946/47 seasons. Fruit was handled as in commercial practice. The treatment was standardized at about 7 mg. per cb. ft. of air for a period of 6 hours, except in the experiments in which gas concentrations and length of treatment periods were studied. The fruit was kept in the packing shed during the period required for completion of all treatments, on average for 5 days, and was then stored for about 5 weeks.

Records of rotting were made twice after approximately 3 and 5 weeks of storage. Four cases of fruit were used for each item of the experiment; the number of fruit in each case varying with the size of the fruit. The temperature of the store room was about 18°C and the relative humidity between 80-95%.

Results

Wastage was chiefly due to diplodia stem-end rot and the moulds due to *Penicillium digitatum* and *P. italicum*, the former being prevalent. Other rot causing fungi found were *Phytophthora* spp., *Trichoderma, Alternaria, Colletotrichum, Oospora, Phomopsis.* The incidence of each of the three main rots and total rotting was recorded. Minor rots are not shown in the table. The percentage of diplodia stem-end rot actually observed, chiefly after 5 weeks storage, is somewhat lower than was to be expected because part of the fruit infected by diplodia succumbs to the more rapidly developing moulds, before any symptoms of stem-end rot are noticeable on the fruit.

Numbers and time of application

As shown in tables II and III, the results generally confirmed those with inoculated fruit and were alike in the two seasons tested.

Two consecutive applications of nitrogen trichloride at 7 mg. per cb. ft. of air for 6 hours and at an interval of 2 days between the two treatments were found to give the most effective control of rotting, viz. a 80—90 per cent. reduction of rot over 5 weeks storage at 18°C, the incidence of rot never exceeding 9 per cent. The time of the first gas application, whether one or more days after picking, did not markedly affect the effectiveness of the treatment. There was some indication that the effectiveness of the treatment can be increased if the first gassing is applied to non-wrapped and non-packed fruit.

The effectiveness of a single application of the gas seems to depend chiefly on the time of application. A single application on the day following picking did not decrease rotting to a sufficient extent. Treatment applied two days after picking showed already a

TABLE II

The effect of single and repeated applications of nitrogen trichloride, and of the timing of applications, on rotting of Shamouti oranges at two temperatures and dosages

	Control	Treated once		Treated twice		Treated
	un-treated	1 day after picking, non-wrapped non-packed	2 days after picking, wrapped packed	1 and 2 days after picking, non-wrapped at first application	2 and 4 days after picking, wrapped	3 times 1, 3 and 5 days after picking, non-wrapp. at first application
I. Picked 10th Febr. 1946, treated with 7 mg. NCl_3 per cb. ft. air for 6 hours, stored at 18°C (each item 800—860 fruits)						
% rot after 25 days						
stem end rot	17.7	10.8	2.7	1.1	0.8	0.8
moulds	13.7	4 2	2.7	1.9	2.5	1.9
total rot	31.4	15.0	5.4	3.0	3.3	2.7
% rot after 38 days						
stem end rot	37.0	15.3	6.8	2.1	2.4	2.0
moulds	22.5	9.4	5.6	3.2	6.4	4.8
total rot	59.5	24 7 ?	12 4	5.3	8.8	6.8
rind injury after 38 days						
percent.	0	1.1	0.6	0.8	1.7	2.1
intensity	-	v e r y		s l i g h t		
II. Picked 10th Febr. 1946, treated with 7 mg. NCl_3 per cb.-ft.-air for 6 hours, stored at 15°C (each item 660-900 fruits)						
% rot after 25 days						
stem end rot	0	0 4	0	0.1	0	0.1
moulds	5.4	2.8	1.0	0.7	1.5	2.1
total rot	5 4	3.2	1.0	0.8	1.5	2.2
% rot after 38 days						
stem end rot	2.8	4.3	0.5	0 1	0.2	0.1
moulds	7.3	3.2	1.2	1.9	2.0	3.0
total rot	10 1	7.5	1.7	2 0	2.2	3.1
rind injury after 38 days						
percent.	0	1.1	0 6	0.8	1.7	2.1
intensity	-	very slight		slight	very slight	
III. Picked 24th Febr. 1946, treated with 13 mg. NCl_3 per cb. ft. air for 6 hours, stored at 18°C (each item 420-650 fruits)						
% rot after 25 days						
stem end rot	1.5	4 0	1.4	0.3	0.6	0.3
moulds	15 2	12.1	3.1	1.4	1.4	7.2
total rot	32.7	16.1	4 4	1.9 ?	2.0	7.7
% rot after 38 days						
stem end rot	39.0	9.0	2 3	0.3	1.0	0.7
moulds	27.4	23 3	7.7	4.8	3.4	16.7
total rot	66 5	32.3	10.0	6 7	5.0	17.5
rind injury after 38 days						
percent.	0	2.4	2.1	14 4	9 6	14.9
intensity	-	slight	moderate		slight	

TABLE III

The effect of single and repeated applications of nitrogen trichloride, and of the timing of applications, on rotting of Shamouti oranges in 1946/47

7 mg. NCl_3 per cb. ft. of air applied for 6 hours; each item 580—800 fruits

Treatment	Percentage rot						Rind injury after 38 days	
	after 30 days			after 45 days				
	moulds	stem end rot	total	moulds	stem end rot	total	%	intensity
Control, untreated, wrapped & packed 1 day after picking	6.4	1.4	7.7	10.3	3.2	13.5	0.9	very slight
Control, untreated, wrapped & packed 4 days after picking	3.9	1.0	4.9	6.6	2.3	8.9	3.3	do.
Gassed *once*, 1 day after picking, non-wrapped*)	3.3	1.4	4.7	5.8	2.6	8.5	1.5	do.
Gassed *once*, 2 days after picking, non-wrapped	2.6	0.6	3.2	4.8	0.9	6.1	0.6	do.
Gassed *once*, 3 days after picking, non-wrapped	0.3	nil	0.6	0.7	nil	1.0	1.7	do.
Gassed *once*, 2 days after picking, wrapped	1.4	0.6	1.9	2.8	0.6	3.5	1.9	do.
Gassed *once*, 3 days after picking, wrapped	0.8	nil	0.8	1.7	0.6	2.2	0.7	do.
Gassed *twice*, 1 and 3 days after picking, non-wrapped	0.5	nil	0.5	0.9	0.2	1.2	1.7	do.
Gassed *twice*, 2 and 4 days after picking, non-wrapped	0.5	0.2	0.6	1.1	0.3	1.4	1.3	do.
Gassed *twice*, 3 and 5 days after picking, non-wrapped	0.3	nil	0.3	1.0	0.1	1.2	1.2	do.
Gassed *twice*, 2 and 4 days after picking, wrapped	0.4	0.1	0.9	1.6	0.4	2.4	5.6	do.
Gassed *twice*, 3 and 5 days after picking, wrapped	0.8	nil	0.8	1.7	0.1	2.1	1.1	do.

*) The fruit designated as "non-wrapped" was wrapped one day after treatment. Where two applications were made, the fruit was wrapped after the first gassing. The fruit designated as "wrapped" was wrapped one day before treatment.

marked reduction of rots, but highest effectiveness was obtained where the gas was applied three days after picking. Delay of wrapping and packing for four days after picking decreased the incidence of rotting to some extent in untreated fruit as well (table III). The effect of time of wrapping on the effectiveness of a single application of the gas was not consistent.

Three consecutive applications at intervals of 2 days, were tried only in one season (tables II, III) and did not generally give better decay control than two applications.

Concentration and period of application

As stated above, the standard concentration of nitrogen trichloride used in most of the tests was 7 mg. per cb. ft. of air, in agreement with the results of KLOTZ's (1) experiments and with Californian practice. Furthermore, our tolerance test (cf. below) proved that this concentration could be used without causing noticeable injury to the rind of the fruit.

To determine the most effective concentration of the gas for controlling rots, concentrations of 4, 7, 10 and 13 mg. nitrogen trichloride per cb. ft. of air were tested. The highest concentration of 13 mg. per cb. ft. of air was tested only once at the end of February 1946. The results are not strictly comparable with those obtained with 7 mg. NCl_3 in other experiments a fortnight earlier; it appeared, however, that 13 mg. per cb. ft. of air failed to improve wastage control as compared with a concentration of 7 mg. (table II). Moreover, 13 mg. caused more extensive and pronounced rind injury than the lower dose. For this reason the concentration of 13 mg. per cb. ft. was omitted in the 1947 tests. The results of these tests are shown in table IV. The total amount of rotting of untreated fruit was much lower in this than in the previous year. This may be due to conditions in the grove and to climatical factors.

TABLE IV

The effect of various concentrations of nitrogen trichloride, when applied for 6 hours, on rotting of Shamouti oranges stored at 18°C

(each item 600—720 fruits)

Date of picking	NCl_3 per cb.ft. of air	No. of applications	Percentage rotting after 27 days			Percentage rotting after 41 days			Rind injury after 41 days	
			stem end rot	moulds	total	stem end rot	moulds	total	%	intensity
6.1.47	untreated		1.1	1.4	2.6	6.8	2.3	9.1	nil	
	4 mg.	once	3.3	0	3.3	6.8	0.1	7.0	do.	
8.1.47	untreated		1.4	5.4	6.8	3.6	7.6	11.3	nil	
	7 mg.	once	1.7	1.2	2.9	3.9	1.6	5.5	do.	
	7 mg.	twice	0.4	0.9	1.3	2.2	1.4	3.6	do.	
7.1.47	untreated		0.3	2.2	2.5	2.8	3.8	6.6	nil	
	10 mg.	once	1.5	1.2	2.8	2.2	1.8	4.0	do.	
24.2.47	untreated		2.3	6.7	8.9	6.8	10.9	17.7	0.0	nil
	6 mg.*)	once	0.2	2.3	2.5	0.6	3.9	4.7	0.6	very slight
26.2.47	untreated		2.9	5.5	8.3	7.7	11.1	18.8	0.0	nil
	7 mg.	once	0.8	1.5	2.5	1.9	2.6	4.7	1.5	very slight
	7 mg.	twice	0.0	1.7	2.0	0.5	3.2	4.3	1.0	do.
25.2.47	untreated		0.6	5.2	5.8	3.2	8.4	11.6	2.0	do.
	10 mg.	once	0.6	2.5	3.5	1.0	3.6	5.5	0.7	do.

*) Though a concentration of 4 mg. was intended, the actual average concentration obtained was 6 mg.

The reduction of rotting by the respective concentrations of NCl_3 was not very consistent, and this was apparent especially in the January test, where very little or no control of stem end rot was obtained. In the later tests the decrease in rotting was more pronounced. 7 mg. per cb. ft. of air gave the best effect in the control of both stem end rots and moulds. Further tests will be necessary to confirm these results.

TABLE V

The effect on the rotting of Shamouti oranges of the period over which nitrogen trichloride is applied

Rate of application: 7 mg. NCl_3 per cb. ft. of air
(each item 600—720 fruits)

No. of applications	Length of application period (in hours)	Percentage rotting after 27 days			Percentage rotting after 41 days			Rind injury after 41 days	
		stem end rot	moulds	total	stem end rot	moulds	total	%	intensity
		I. *Fruit picked 8th January* 1947							
	untreated	1.4	5.4	6.8	3.6	7.6	11.3	nil	
once	3	2.6	2.5	5.1	5.2	3.5	8.7	do.	
„	6	1.7	1.2	2.9	3.9	1.6	5.5	do.	
twice	3+3	1.3	0.7	2.0	2.2	1.0	3.2	do.	
„	6+3	1.6	1.6	3.2	2.2	2.8	4.9	do.	
„	6+6	0.9	0.9	1.3	2.2	1.4	3.6	do.	
		II. *Fruit picked 26th February* 1947							
	untreated	2.9	5.5	8.3	7.7	11.1	18.8	nil	
once	3	1.4	3.5	5.3	2.4	6.1	9.7	do.	
„	6	0.8	1.5	2.5	1.9	2.7	4.7	1.5	very slight
twice	3+3	0.8	2.8	3.8	2.2	4.5	7.0	1.7	do.
„	6+3	0.3	2.5	3.0	0.3	5.6	6.2	0.6	do.
„	6+6	0.0	1.7	2.0	0.5	3.2	4.3	1.0	do.

Table V summarises the results obtained with regard to the effect of the length of the period over which the gas is applied to the fruit. When the fruit was treated once, application over 6 hours was found to be much superior to that over 3 hours. When fruit was treated twice the differences were less pronounced, but it seems that in this case, too, treatment periods of 6 hours give the most effective control.

Storage temperature

The effect of storage temperature on the incidence of rotting and on the efficacy of nitrogen trichloride in orange decay control is shown in table II. The two temperatures compared were a constant level of 18°C and current packing-shed temperatures with an average of 14°C, a maximum of 20°C, and a minimum of 10°C. The incidence

of rot at the lower temperature in general was very low in all cases, in non-treated as well as in treated fruit. This indicates an inhibiting effect on rotting of the temperature itself. This effect is most evident in the case of stem end rot (*Diplodia*), which is known to be retarded in its development at temperatures as low as 14°C, and fails to develop below 12°C. In our experiments the efficacy of nitrogen trichloride treatment was hardly affected by the level of temperature.

III. EFFECT OF NITROGEN TRICHLORIDE ON FUNGI

KLOTZ (1) has shown that concentrations of 4—6 mg. NCl_3 per cb. ft. of air for a period of 30 minutes are lethal to the spores of *Penicillium digitatum, P. italicum, Colletotrichum gloeosporioides, Alternaria citri and Phytophthora citrophthora.*

Our experiments were chiefly designed to determine the effect of nitrogen trichloride on spores and mycelium of *Diplodia*, but tests were also made with *Penicillium digitatum, P. italicum, Trichoderma viride, Alternaria* sp., *Colletotrichum gloeosporioides* and *Phytophthora citrophthora.*

Methods

The effects of time of exposure, substrate, and absorption of the gas, on the mycelium and conidia of the fungi were studied. Three different methods were used in the course of the experiments:

(a) KLOTZ's method of placing a water suspension of spores and mycelium on filter paper in Petri dishes, exposing them to the gas, pouring agar on the filter paper after exposure, and subsequent counting of any colonies that may develop.

(b) A suspension of spores and mycelium in water was placed on a cover slip and exposed to the gas. After exposure the cover slip was placed on potato dextrose agar so that the treated fungus contacted the agar, and was incubated at 25°C. Percentage of spore germination and growth rate of the culture were recorded.

(c) A suspension of spores and mycelium was placed in the centre of the surface in a Petri dish, then exposed to the gas and incubated at 25°C for 2-4 days. Since it was shown in separate tests that agar retains the gas after exposure, transfers of the spore suspension were made after gassing from the gassed plates to untreated ones, which were then incubated. To investigate the effect of the gas on mycelium, spores or mycelium were sown on agar plates two days before gassing and the gas was applied to the growing culture prior to the appearance of conidia. After gassing transfers were made of the margin of the culture.

The concentration of the gas was maintained at a level of approximately 7 mg. per cb. ft. of air.

Results

Six hours' gassing killed spores and mycelium grown on agar of *Diplodia natalensis, Penicillium digitatum, P. italicum, Trichoderma sp., Colletotrichum gloeosporioides, Alternaria sp.,* and *Phytophthora citrophthora.*

In another test designed to determine the minimum period of exposure liable to kill spores of *Diplodia natalensis* and *Penicillium digitatum* on agar, spores of both these fungi failed to germinate when a spore suspension of the fungus sown on agar was exposed to nitrogen trichloride for 30 minutes. On the other hand, when sown on cover slips, the spores were in most cases only partly killed but the growth of surviving conidia was much retarded. Mycelium when grown on agar plates and transferred after gassing to fresh plates, was always killed; but in the original plate the fungus continued to grow in some cases, although its development was always retarded. It is assumed that this incomplete killing may be due to some spores in the centre of the plate that escaped the gas (table VI).

The more pronounced inhibiting effect of nitrogen trichloride on spores sown on agar as compared with those on cover slips, seems to be related to the difference in the moisture content of the spore. In the case of spore suspension on cover slips, the water around the spore dries out quickly and the spores are left dry during the major part of the treatment, whereas on agar most of the spores are in contact with a wet surface from sowing throughout the period of treatment. Furthermore, the gas penetrates the agar to some extent and can therefore affect the spores from all sides, which is not the case with spores sown on glass cover slips.

As a possible explanation of these results it may be suggested that nitrogen trichloride does not readily kill dry spores that have not yet begun to germinate. On the other hand, spores which by taking up moisture (from the agar) already entered the stage of germination appear more susceptible to the gas.

This may also be the reason for the fact that the gas when applied to fruit immediately after picking is less effective in decay control than when applied 2 or 3 days after picking. During these 2 or 3 days most of the fungus spores harbouring on the surface of the fruit may begin to develop and are then more susceptible to the gas.

TABLE VI

*Effect on germination and growth of Diplodia **natalensis** of various periods of exposure to 7 mg. nitrogen trichloride per cb. ft. of air*

Test No.	Period of exposure in hours	mycelium: growth on agar: original	mycelium: growth on agar: transfer	Spore suspension in water: on cover slips: growth	Spore suspension in water: on cover slips: germination	Spore suspension in water: growth on agar: original	Spore suspension in water: growth on agar: transfer	Klotz's method	Temperature during gassing
I	2	××××	OOOO	++		××××			
	3							××	
	6							××	
II	6	OO	OO	OO	OO	OO			17-21°C
III	2	OOOOO×	OOOOOO						24-32°C
	6	OOOOOO	OOOOOO			OOOOOO	OOOOOO		
IV	1	O××	OOO			OOO	OOO		
	2	OO×	OOO			OOO	OOO		30°C
	6	O××	OOO			OOO	OOO		
V	½			××××××	50%	OOOOOO			
	1			××××××	30%	OOOOOO			27-37°C
	5½			××××××	10-20%	OOOOOO			
VI	1	OOO	OOO	×××	>75%	OOO	OOO		
	2	OOO	OOO	×××	33%	OOO	OOO		15-18°C
	6	OOO	OOO	×××	<10%	OOO	OOO		
	Controls: In all tests abundant growth 1 or 2 days after transfer								

Symbols: + normal growth
× retarded growth
O no growth

The number of symbols indicates the number of replicates in each test.

IV. EFFECT OF NCl_3 TREATMENT ON APPEARANCE AND QUALITY OF SHAMOUTI ORANGES

(a) *Preliminary tolerance tests with non-wrapped Shamouti oranges*

The tolerance to nitrogen trichloride of Shamouti oranges, i.e. the maximum concentration of the gas to be applied to the fruit without causing noticeable injury, was determined in four trials. The first test was performed on the 13th January, 1946 (approximately 1½ months after the beginning of the picking season). Further tests were made at the end of the picking season. The concentrations tested were 7, 10 and 13 mg. of the gas per cb. ft. of air. The period of treatment was 6 hours. Samples of ungraded and non-wrapped fruit, originating from the Research Station's grove, were treated in field boxes in a tent. After treatment, the fruit was stored non-wrapped in a packing shed and examined after 2 and 15 days.

Injury was observed to consist of slight pitting of brownish colour, and occurred almost exclusively on fruit damaged by sun, and on the sun-burnt area only. 7 mg. gas per cb. ft. of air for a period of 6 hours did not cause any injury. 10 mg. gas per cb. ft. caused 5.3 percent of very slight injury to the rind of the fruit, whereas untreated fruit remained entirely sound. 13 mg. gas per cb. ft. caused more pronounced injury, but in general the percentage of injured fruit was not higher that that caused by 10 mg. per cb. ft. Control fruit in this set of experiments showed also 1.6 percent of very slight pitting on the sun-burnt areas. All the injury to the fruit was noticeable two days after treatment and did not expand much during the next two weeks, but the brown colour of the injured area deepened with the length of time. The tolerance of partly green fruit was found to be equal to that of fully coloured mature fruit.

According to the above results, treatment of Shamouti with the concentration of 7 mg. nitrogen trichloride per cb. ft. of air for a period of 6 hours was chosen as standard treatment in the experiment described above.

(b) *Commercially handled fruit after storage at 18°C*

After 5 weeks' storage at 18°C oranges treated with nitrogen trichloride at 7 mg. per cb. ft. for 6 hours generally remained firm and were of good appearance, somewhat lighter in colour and much cleaner than untreated fruit. The greater cleanliness of treated fruits, as compared with untreated ones, seems partly to be due to the inhibiting effect of nitrogen-trichloride on fungi, especially such as sooty moulds, which grow superficially on untreated fruit with their blackish mycelium giving the fruit a dirty appearance. It may further be assumed that nitrogen trichloride has a bleaching effect on the spores and mycelium of the fungi and on other particles of dirt.

The taste of the fruit after treatment is normal and pleasant, and superior to that of untreated fruit stored in the same way. The taste of untreated fruit was found to be affected by the great number of mouldy fruit in the same case.

Nitrogen trichloride failed to injure the fruit or caused only slight damage, that did not markedly affect the market value. What injury there was, assumed the form of lateral pitting or of slightly sunken areas around the bottom of the fruit. Cultures of the affected rind or button did not, in general, yield fungal growth.

There is some indication that relatively high storage temperature, increasing numbers of gas applications, and gas concentration exceeding 10 mg. per cb. ft. of air increase the incidence and intensity of rind injury. It was further evident that most of the damage occurred towards the end of the picking season, in February and March.

SUMMARY

Experiments were carried out in the 1945/46 and 1946/47 picking seasons to test the effectiveness of nitrogen trichloride treatment (commercially known as "Decco" process) in the control of Shamouti orange rots.

In tests with inoculated fruit (wounded or non-wounded) as well as with non-inoculated fruit, NCl_3 effectively controlled the principal rots, viz. stem end rot (*Diplodia natalensis*), green mould (*Penicillium digitatum*), and blue mould (*P. italicum*).

Two successive applications of NCl_3 at an interval of two days, with the gas applied at the rate of 7 mg. per cb. ft. of air for 6 hours, gave the best results and reduced rotting after 5 weeks' storage at 18°C by 80—90 percent. The timing of these applications in relation to the time of picking did not materially affect their efficacy. On the other hand, single applications of NCl_3 were less effective when made the day after picking than when made 2 or even better 3 days after picking; in the latter case they were almost as effective as two consecutive applications. — Three applications were not, in general, superior to two.

Concentrations of 5, 7, 10 and 13 mg. NCl_3 per cb. ft. were tested. 7 mg. proved the most effective in controlling rots without noticeable injury to the rind.

Reduction of storage temperature from 18 to 15°C retarded development of both stem end rots and moulds in treated as well as untreated fruit. The gas, however, was almost equally as effective at the lower as at the higher temperatures.

As regards the effect of NCl_3 on the fungi causing orange decay, application of 7 mg. per cb. ft. of air for 6 hours killed the spores and mycelium of *Diplodia natalensis, Penicillium digitatum, P. italicum, Trichoderma sp., Colletotrichum gloeosporioides, Alternaria sp.*, and *Phytophthora citrophthora* on agar plates, but on glass cover slips these fungi were only partly killed and in part merely retarded in their development. On agar, even 30 minutes' exposure to

the above treatment killed spores and mycelium of *Diplodia natalensis* and *Penicillium digitatum*..

7 mg. NCl_3 per cb. ft. of air failed to affect the rind of Shamouti oranges or affected it only very slightly. Repetition of applications, increased gas concentrations and higher storage temperatures seem to increase the incidence and intensity of rind injury.

Treated fruit was of good appearance, remained firm, had a slightly lighter colour and was cleaner than untreated fruit.

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NOTES

BROWN ROT OF POTATOES IN PALESTINE

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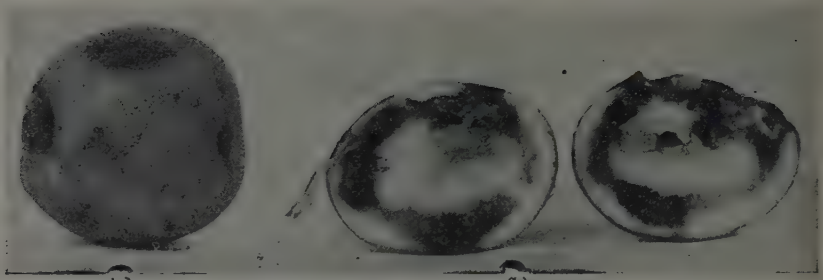
Brown-rot like symptoms on potatoes were observed in Palestine for the first time simultaneously in three different places in the spring 1946 and in spring and autumn 1947. Great damage was caused to the tubers especially at Hadera in 1947, where the yield of the crop was decreased from 2½-3 tons to 1 ton per dunum. The disease was observed on the two main varieties grown in Palestine "Up to date" and "Arran Banner", and to a lesser degree on "Kerr's Pink". The disease affected plants grown from tubers imported from England as well as plants grown from local, once grown seed.

In all these cases, the disease was observed on plots where potatoes were planted for the first time, as well as on those on which potatoes have been grown in the previous season.

The first symptoms of the disease appeared in the field in the middle of April on a small number of plants. The infected plants showed wilting of the leaves which started at first from their top progressing downwards, and later also from their middle and lower parts progressing upwards and downwards. The disease spread quickly to neighbouring plants, and in two to three weeks quite large bare spots could be seen amidst the healthy parts of the field. The tubers of infected plants, examined at an early stage of the disease, were of normal, healthy outward appearance. Cutting the tubers revealed, however, a light brown ring around the vascular elements, which became darker in colour when exposed to the air. When slight pressure was applied to that cut, a white to cream coloured exudate oozed from the vascular elements. These symptoms, which occurred at first mainly on small young tubers, were observed to appear on bigger tubers at a later stage. The infection, at an early stage, was localised in the vascular ring and the stem-end, and later radiated into the eyes of the tubers. A slimy ooze exuded from the eyes, and particles of soil adhered to it. In many cases, total breakdown of the tubers ensued. This phenomenon was never observed on the set-tubers. In the later stages of the disease the collars were also affected, and exuded a slimy milk-like ooze. The roots, however, appeared healthy.



Text-fig. 1. Pseudomonas solanacearum on potato tubers.
(a) Particles of soil adhering to the exudate from the eyes.
(b) Cut through a tuber in an advanced stage of infection.

The symptoms of the disease occurring in the field and the appearance of the infected tubers suggested that it was caused by *Pseudomonas solanacearum,* which is known to cause brown rot on potatoes and several other plants.

A study of the infected tubers showed that the disease was associated with bacteria. Free hand sections stained by Claudius' method revealed numerous bacteria in the vascular elements of infected tubers. Direct smears of the ooze stained with Loeffler's methylene blue revealed numerous bacterial organisms. Gram stain showed the presence of Gram negative bacteria. A number of different organisms were isolated from infected tubers. The majority of them were discarded as saprophytes. One of them, however, was in some respects similar to *Ps. solanacearum.* But as its sugar reactions were not identical with those given in Bergey's manual for *Ps. solanacearum,* and as we failed at first to obtain positive results in infection experiments, we could not be certain whether or not this was also a saprophyte. At this stage Dr. W. J. Dowson, of the University of Cambridge, England, agreed to cooperate in the identification of the cause of the disease. Dr. Dowson, to whom our thanks are due for undertaking this task, isolated from infected tubers sent to him for examination, among a number of saprophytes, a bacterial organism which he identified as *Pseudomonas solanacearum.* This has been found to be identical with the organism isolated by us and mentioned above as a doubtful parasite, and thus confirmed the assumption that the disease was caused by *Pseudomonas solanacearum.*

NEMATODES ON GLADIOLUS CORMS

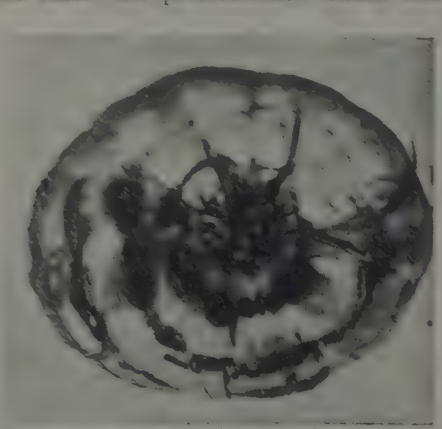
By MATILDA CHORIN and G. MINZ

Division of Plant Pathology, Agricultural Research Station of the Jewish Agency for Palestine, Rehovot

Several cases of gladioli being affected by nematodes have occurred in Palestine in recent years. In 1943 the roots of gladioli were found to be affected by nematodes, though not to a very large extent. In 1947 the corms themselves were markedly affected in various localities comprising the Samaria district, the Valley of Esdraelon, and various points in the coastal plain.

Description

On the lower surface of gladiolus corms blister-like protuberances give rise to black cracked scab lesions or breaks. These are apparent especially between the basal plate and the lower end of the first and second bulb scale; occasionally breaks appear also on the third scale. Sometimes the blister-like protuberances remain intact and do not disrupt.



Text-fig. 1. Underside of gladiolus corm affected by nematodes. Dark scabby lessions or stripes, sometimes split, are apparent.

The breaks form from brown depressions on both sides of the scales. The scale itself protrudes at first, the whole lesion swells and turns light brown, and the scale splits into two rims that diverge progressively and turn dark brown to black. The splits may measure up to 4 mm., and the depression between the rims is scabby. The rims themselves are narrow and light in colour, but occasionally also wide, black and necrotic; they generally protrude.

The spots appear at first singly, but later unite and encircle the corm.

We were unable to determine whether or not the above-ground parts of the plants show any symptoms, because the corms were brought to us after they had been harvested.

Cause

The above symptoms on gladiolus corms were found to be due to the nematode *Heterodera marioni* (Cornu) Goodey. This nematode, which has already been recorded in Palestine on over 200 hosts comprising more than 50 botanical families ("Hassadeh", Vol. 16, p. 316-9, 1936) has so far been found on propagating material only in the case of potato tubers and Dahlia corms.

THE CONTROL OF LICHENS IN CITRUS GROVES

Preliminary Work

By

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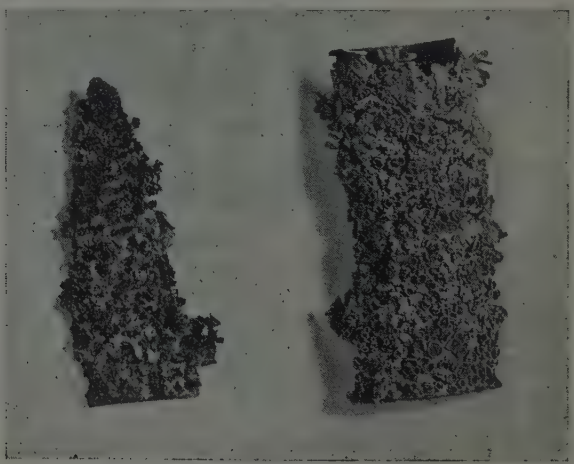
Lichens have always been prominent in the Citrus groves of Palestine, and they often cover the trunks and limbs of the trees with a thick layer of growth. They are particularly in evidence in the citrus groves neglected during the war. The lichen most prevalent in citrus groves is *Xanthoria parietina* (text-fig. 1).



Text-fig. 1. The effect of 'Perenox' spray on the lichen *Xanthoria parietina*.
On the right lichen from unsprayed tree.
On the left: lichen from a sprayed tree — the lobes of the thallus have shrivelled and dried.

Phot. N. Suffrin

The question whether or not lichens are parasitic on citrus trees is still open; in any case they help to worsen the condition of trees weakened by other causes. Numerous growers attempt to remove lichens by scraping the bark in winter. Copper treatments, such as Bordeaux mixture, have also variously been used. However, the profitability of such treatments solely directed against lichens is debatable. Means were therefore sought of combining such treatments with others regularly applied to citrus trees in Palestine; among these the insecticidal treatment most widely applied is undoubtedly the spraying with oil for black scale control. An attempt was, therefore, made to combine a copper treatment for lichen control with the oil spraying against black scale. This combined spray was further intended to check citrus diseases, such as *Diplodia natalensis* and *Phytophthora* spp. Only the results concerning lichen control are dealt with here.

The materials used were —

(a) Shell WA oil at a concentration of 1.75%
(b) 'Perenox' (containing 50% Cu in form of cuprous oxide) at 1/3-1/6%.

In spraying against black scale, oil is applied at a heavy rate, as much as 60 litres per tree being applied to large trees. It was feared that applications at so heavy a rate might be injurious to the citrus trees if normally strong copper concentrations were used. It was, therefore, decided to use 'Perenox' at the low concentration of 1/6% (0.08% Cu) and to compare this with 'Perenox', used at the normal concentration of 1/3% and applied more sparingly.

The trees used in this experiment were small Shamouti oranges on sweet lime stock, in a grove at Mikve Israel, in the Central coastal plain of Palestine. Owing to the small size of the trees the rate of oil spraying was fixed at 30 litres per tree. Treatments were applied on 23rd August 1941, each to one group of 30 trees, with a power sprayer working at a pressure of 500-600 lbs. per sq. in.

The effect of treatments on the lichen was estimated on 10 trees of each plot in the following summer, on 9th July, 1947, by a scale of marks reading as follows: 0 marks — normal, green, healthy appearance of *Xanthoria* (Text-fig. 1, right),

2 marks — yellow or normal colour, thallus shrunk slightly but not uniformly,
4 marks — brown colour, thallus shrunk,
8 marks — thallus dark, dry, peeling off (Text-fig. 1, left).

The results are presented in the following table:—

The effect of oil and copper (Perenox) spray on Xanthoria parietina on orange trees

Treatment	Rate of application per tree	Marks assigned to each tree (0=normal — 8=peeling off)										
		Tree No.										
		I	II	III	IV	V	VI	VII	VIII	IX	X	Mean
Control	—	0	0	0	0	0	0	0	0	0	0	0
Perenox 1/3%	16 litres	1.5	2	4	1.5	6.5	7.5	8	8	7.5	8	5.4
Perenox 1/6%	30 „	5.5	8	8	8	6.5	4	3.5	7.5	8	8	6.7
Perenox 1/6%+ white oil 1.75%	30 „	8	8	6	8	8	7	7	6	8	8	7.4
White oil 1.75%	30 „	0	1.5	0.5	1	1	0	1	1	0	1	0.7

The results show that white oil alone has little effect on the lichen. Application of 1/3% Perenox at a low rate did not give uniform results (1.5 to 8 marks) because coverage was evidently inadequate. Perenox 1/6%, applied at the rate of 30 litres per tree, was satisfactory when used alone, and even better when combined with oil. The oil probably ensured even coverage, so that the trees under the combined treatment received uniformly high marks (6-8).

Acknowledgment

The experiment described here has been rendered possible by the co-operation of Mr. A. Greenberg, Entomologist, Plant Protection Service of the Government of Palestine, and Mr. I. Joffe, Manager of the Citrus groves of Mikveh Israel Agricultural School. Dr. Z. Avizohar-Hershenson assisted in the estimation of results.

Their help is hereby gratefully acknowledged.

עתון לבוטניקה

כרך ו' חוב' א'-ב' סדרת רחבות כסלו תש"ח

אל הקורא העברי

בשעת חרום – שעת מלחמת השחרור של עמנו בארץ – חועמדנו בפני קשיים בלתי-צפויים מראש. משום כך לא יכלנו לצרף לכרך זה של עתוננו את המכומים בעברית שהיינו רגילים לתת. את הקוראים המליחה ונשתדל למלא את החסר בעת הופעת הכרך הבא.

המערכת.

עתון לבוטניקה

מופיע בשתי סדרות

א. סדרת רחובות:

יוצאת לאור ע"י ה. ה. אופנהיימר וי. ריכרט מהתחנה לחקר החקלאות, רחובות, ישראל. לפי תכניתנו כל כרך בסדרה זו יכיל 2 חוברות (200—300 עמודים) שתופענה משך שנה ככל האפשר.

ב. סדרת ירושלים:

יוצאת לאור ע"י חבר העובדים של המחלקה לבוטניקה באוניברסיטה העברית בירושלים. לפי התכנית כל כרך בסדרה זו יכיל 4 חוברות (300—400 עמודים) שתופענה משך שנה ככל האפשר.

את דמי החתימה יש לשלם למפרע ע"י שק או המחאת דואר. מחיר החתימה הוא:

2.000 לא"י לכרך, בעד שתי הסדרות

1.250 לא"י לכרך, בעד סדרת ירושלים בלבד

0.900 לא"י לכרך בעד סדרת רחובות בלבד.

בסכומים אלו נכללים גם דמי המשלוח.

את דמי החתימה ואת המכתבים הנוגעים בעניני המערכת יש לשלח לפי הכתובות הבאות:

לסדרת ירושלים: עתון לבוטניקה, ת.ד. 620, ירושלים.

לסדרת רחובות: עתון לבוטניקה, ת.ד. 15, רחובות.

במכתבים הנוגעים בשתי הסדרות אפשר לפנות לכל אחת מהכתובות הנ"ל.

את הכרכים הראשונים של סדרת רחובות אפשר להשיג במחירים אלו:

כרכים א', ב' וג' — 0.750 לא"י כל אחד

כרך ד' וה' — 0.900 לא"י.

דפוס מ. שהם, תל-אביב, רח' פין 6, טל. 2239

סדרת רחבות כרך ו', חוב' א'-ב'

כסלו תש"ח

עתון לבוטניקה

סדרת רחבות

(למנים רשימות לבוטניקה ומדעי הגננות)

יוצא לאור על ידי

ה. ר. אופנהימר וי. ריכרט

מהתחנה לחקר החקלאות, רחבות, ישראל

מזכיר המערכת:

י. פלטי

רחבות, ישראל